THE

AMERICAN

JOURNAL OF SCIENCE AND ARTS.

[THIRD SERIES.]

ART. XIII.—*On the Minute Structure of the Solar Photosphere;* by S. P. LANGLEY.

IT will be within the memory of all concerned in such studies, that when, in 1861, Mr. Nasmyth announced the discovery of what he called the "willow-leaf" structure of the solar surface, a lively interest was excited, and that a subsequent discussion arose in which some eminent observers took part. It will be remembered also what a diversity of opinion was exhibited, not only as to the nature of the structure, but as to the fact of its existence, concerning which the most contradictory opinions were emitted. It was pointed out that Mr. Nasmyth's estimate of the size of these bodies was inconsistent with the difficulty which was found in seeing them. Mr. Dawes, than whom no one stood higher as an observer, denied their existence. Father Secchi doubted the accuracy of the description, while asserting that he had seen multitudes of small discrete bodies of much less size than the so-called willow leaves. Mr. Stone and Mr. Donkin found the minute components of the photosphere to resemble rice-grains, and so on with others. As each observer maintained a different opinion, in spite of the interest of the discussion, no conclusive result was reached; for it was a peculiar feature of this remarkable controversy that it did not arise concerning an interpretation of fact, but as to the reality of the fact itself, concerning which, with the best instruments in practised hands, it seemed difficult to find any two observers to agree. The state of our present knowledge on the point can hardly be considered satisfactory, for no telescopic observations of special value have been since added of which I am aware, with the

exception of some early ones by Lockyer and Huggins (a paper by the latter being accompanied by a suggestive drawing),* and of some illustrated by Secchi's excellent sketches. The difficulties of observation are in fact extreme, they are enhanced by want of a precise nomenclature, and their elucidation is not easy without elaborate drawings. The present article, which partly anticipates a prospective and completer publication on the part of the Allegheny Observatory, is meant as a help to their removal, and as a contribution of material for a judgment upon the theories of the solar circulation due to Faye, Kirchoff, Lockyer, Secchi, Young, Zöllner, and other eminent students of Solar Physics. As it is based only upon direct telescopic study of the minute components of the photosphere, it will offer a distinct point of view from that taken by the spectroscopist, and though therefore incomplete, its testimony to the action of solar currents will yet have a certain value from the fact of this independence.

Most of the minuter phenomena to be described are unrecognizable except with large apertures, which, in spite of the abundant light, are indispensable for reducing irradiation. That of the equatorial of the Allegheny Observatory is thirteen inches, but when we use so large an instrument on the sun, we find two principal difficulties. The first, arising from the concentrated light, can be mitigated by optical aids. By the liberality of a citizen of Pittsburgh, the equatorial has been supplied with several special accessories for such study, the most essential of which is the polarizing eye-piece, which, in the form devised and employed here, presents a solar image free from color and of any brightness desired. To secure the rapidity needed in sketching objects whose forms are so changeable without sacrificing accuracy, Mr. Rogers, of the Harvard College Observatory, has had the goodness to rule for me one of his very exact reticules on thin glass, which for the present purpose is divided by faint lines into squares, the side of each being one one-hundredth of an inch, the value of which in the solar focus is $11''{\cdot}55$. The Filar micrometer is of course also employed where its use is appropriate.

The second and more formidable difficulty arises from the disturbance of our own atmosphere, and for this there is no present remedy but assiduity and patience.

It may be stated generally that it will be useless to look for the minuter details described, whatever the power of the telescope, save in exceptionally good definition. In such an investigation, drawings are at present indispensable. Photography in the hands of Messrs. De la Rue and others has been of great service in furnishing unquestionable data for the student of the

* See Monthly Notices Roy. Ast. Soc.; also, Proctor, "The Sun."

laws which govern the solar rotation and the motions of the spots in longitude and latitude, and all are familiar with the results obtained by Mr. Rutherfurd; but however excellent these are, they show that photography in the most skillful hands is at present incompetent to seize multitudes of details which the eye recognizes. Drawings, then, are necessary, but rather such as imitate the fidelity of the topographical draughtsman, than such as aim chiefly at striking pictorial effect; and in the absence of the skill of an artist, I am used to try to secure accuracy by reducing everything as far as is possible to micrometric measurement.

Before we turn with these aids to the study of the photosphere, it will be well to describe briefly appearances presented by the solar surface in telescopes of moderate size.

Here we see a disk of nearly uniform brightness, which is yet sensibly darker near the circumference than at the center. Usually seen relieved against this gray and near the edges, are elongated and irregular white patches (*faculæ*), and at certain epochs trains of spots are scattered across the disk in two principal zones equidistant from the solar equator. On attentive examination it is further seen that the surface of the sun everywhere—even near the center and where commonly neither faculæ nor spots are visible—is not absolutely uniform, but is made up of fleecy clouds, whose outlines are all but indistinguishable. The appearance of snow flakes which have fallen sparsely upon a white cloth, partly renders the impression, but no strictly adequate comparison can perhaps be found, as under more painstaking scrutiny, we discern numerous faint dots on the white ground, which seem to aid in producing the impression of a moss-like structure in the clouds, still more delicate, and whose faint intricate outlines tease the eye, which can neither definitely follow them, nor analyze the source of its impression of their existence.

These appearances have been mentioned, lest they should be confounded in any way with the far minuter structure now to be described.

Under high powers used in favorable moments, the surface of any one of the fleecy patches is resolved into a congeries of small, intensely bright bodies, irregularly distributed, which seem to be suspended in a comparatively dark medium, and whose definiteness of size and outline, although not absolute, is yet striking by contrast with the vagueness of the cloud-forms seen before, and which we now perceive to be due to their aggregation. The "dots" seen before are considerable openings caused by the *absence* of the white nodules at certain points, and the consequent exposure of the gray medium which forms the general background. These openings have been called pores;

their variety of size makes any measurements nearly valueless, though we may estimate in a very rough way the diameter of the more conspicuous at from 2″ to 4″. The bright nodules are themselves not uniformly bright, (some being notably more brilliant than their fellows and even unequally bright in portions of the same nodule), neither are they uniform in shape. They have just been spoken of as relatively definite in outline, but this outline is commonly found to be irregular on minute study, while it yet affects, as a whole, an elongated or oval contour. Mr. Stone has called them rice-grains, a term only descriptive of their appearance with an aperture of three to four inches, but which I will use provisionally. It depicts their whiteness, their relative individuality, and their approximate form, but not their irregular outline, nor a certain tendency to foliate structure which is characteristic of them, and which has not been sufficiently remarked upon. This irregularity and diversity of outline have been already observed by Mr. Huggins. Estimates of the mean size of these bodies vary very widely. Probably Mr. Huggins has taken a judicious mean in averaging their longer diameter at 1″·5, and their shorter at 1″, while remarking that they are occasionally between 2″ and 3″ and sometimes less than 1″ in length.* Estimates of their number are few and more or less conjectural. Mr. Dunkin, using about four inches aperture, found between two and three hundred of them in a space 56″ by 48″. If we call the number two hundred and fifty, we have their average distance apart about 3·4′ $\left(=\sqrt{\frac{56\times 48}{250}}\right)$, which is certainly too great. In the almost total absence of micrometric determinations, the following, though imperfect, will have interest. With the Rogers micrometer and near the center of the sun, with a power of 240 and an aperture of 9 inches, 18 rice-grains were counted in one square (11″·6 on the side). In the next square there were 15, in the next 23. These differences are not so much due to imperfect estimation as to a real irregularity of distribution. On another occasion, with a higher power, 15 rice-grains were counted in a line whose length was 18″·87 and on an adjacent part of the disc, in the same length, 12. From the mean number in these squares and the value of the side of a square in arc, we deduce 2″·57 as the distance between the centers, while with the higher powers we obtain a value of but 1″·42, with every increase of telescopic power the number of minute bodies counted as rice-grains thus being

* It is well to remember that even upon this estimate each of these "minute" bodies is larger than Great Britain.

increased and the mean distance between their centers diminished.*

In moments of rarest definition I have resolved these "rice-grains" into minuter components, sensibly round, which are seen singly as points of light, and whose aggregation produces the "rice-grain" structure. These minutest bodies, which I will call *granules*,† it will appear subsequently can hardly equal 0″·3 in diameter, and are probably less. (Secchi is the only observer, as far as I know, who appears to have seen and measured them. He observed them in the edges of the pores, and reckons their size at ″·$\frac{1}{3}$ to ″·$\frac{1}{5}$, but does not estimate their number or point out their relations to the "rice-grains.") They are irregularly distributed, with a tendency to aggregation in little clusters (the clusters being the rice-grains), and their existence accounts for the diversity and irregularity in the outline of the latter, Mr. Huggins has acutely remarked upon, while it of course makes clear the reason of the apparent increase in the number of "rice-grains" with increasing telescopic power. The drawing gives in the two squares distinguished by a heavy outline, transcripts of specifically discriminated "rice-grains," and their component granules, as they appeared projected upon the squares of the Rogers' reticule when powers of from four to eight hundred were advantageously used with the full aperture of thirteen inches. The granules are the minute bodies recognizable as forming the not very definite clusters. These clusters are, as I have said, the "rice-grains." which appear better defined with smaller apertures, but seen under such powers lose in part their individuality.‡ The drawing will help explain the difficulties in the measurement, and the varying estimates, for we see here that the "rice-grain" is scarcely an entity, but that the term (if still retained) should merely convey our recognition of the fact that there is a tendency in the granules to unite in clusters, and in this sense only I will continue to use it. The apparently vacant spaces may contain more or less of partly luminous granules, as I am inclined to believe they do, without being able to obtain certitude. Whether we consider the granules the luminous summits of ascending currents of gases dissociated at lower depths and becoming incandescent at the surface, or whatever physical

* There is no antecedent improbability in the idea that they are more numerous in certain latitudes than in others, but if there be a difference, it is inconspicuous.

† As this word is already in use, with another meaning, attention should be given to the restricted and definite significance which is here assigned to it.

‡ I have been led from several independent observations to estimate that the longer axes of the clusters lie in a majority of cases nearly parallel to the solar equator, and this, with certain appearances associated with the granules, makes me think that there is a *drift* of the whole photosphere in the same direction. At the same time, I wish to await more of the rare opportunities for these difficult measurements before announcing this as a fact not open to question.

theory we adopt, we may admit the contingency of a more general distribution than is at first apparent, while recognizing that we can number those distinctly visible, and can compute the area they expose, without fear that our estimate will induce material error from the neglect of the existence of other of these bodies relatively non-luminous, which with more powerful instruments might conceivably be discerned.

In fact, the prevalent impression that the brilliant bodies to which the photospheric light is chiefly due are so closely set that only minute dots or shades of thread-like narrowness appear between, is, I venture to state, incorrect. I hardly think it can be shared by one who, after his attention is directed to this point, has the opportunity of studying them under circumstances of reduced irradiation, when these bodies are seen to occupy the smaller portion of the area they at first appear to fill. Independent calculations will reduce this area still farther. The number of granules varies widely, there being commonly from three to ten to the rice-grain, while a count of individual granules with the highest powers gives from eighty to one hundred to each of the squares. More might doubtless be reckoned by powers which subdivided the granule, but this would not affect the estimate of their aggregate area. If, to allow the widest latitude for errors of observation, I assume that the granule may be as much as $''\cdot4$, and the number to the square two hundred, I still find that the properly luminous area is *less than one-fifth* of the solar surface.

We are now prepared to study the minute structure of the photosphere under another aspect, as it appears in the spots. It is impossible to make such a drawing as that here given from any single delineation, owing to the rapidity with which spots change their form. I have accordingly, while taking the general contour and many details from drawings of the great spot of March 5 and 6, 1873, added the results of numerous studies of detail in other spots, made during the past two years. Such a method has obvious drawbacks, in a liability to exhibit features individually true in a connection in which they would not be found in nature. There is no alternative, however, until solar photography has made further advances; and I have used my best pains to combine only such features as belong in organic connection. I have made it a rule to set down only so much as was unquestionably seen, and therefore to give nothing which was partly seen, partly inferred, and to make the annexed drawing as far as possible a faithful transcript of sketches taken at the telescope, and which were, whenever possible, completed and compared before leaving it.

To represent the gradations of light from the intensest splendor to the darkness of the nuclei, we have here only the limited range between a white and a black pigment. This almost compels partial falsity in the degrees of shade, and there is, for instance in the drawing, a relative exaggeration of the shade which marks the outer boundary of the penumbra, and without which the important details would be hardly visible. The drawing is crossed by fine lines which represent squares of the Rogers' reticule projected on the sun, and it will be convenient to remember that the side of each corresponds very nearly to a linear measure of 5,000 miles. The line marked H corresponds nearly to the trace of the ecliptic; lines parallel to it are lettered, and those perpendicular to it numbered, so that by J_{13}, for example, we may denote the part of the spot near the intersection of "J" and "13."

In approaching the spot, the photosphere becomes usually very slightly brighter, and it is more difficult to distinguish individual granules till just at the edge of the penumbra. Here the continuity of the photosphere is *suddenly* interrupted. The penumbra is usually darkest around this edge, the shade defining the granules; which here appear to be elongated, while some are apparently pulled out into long filaments, which cross the outer penumbral shade without a diminution of brilliancy. Then the penumbra grows brighter to the inner edge, but not with a uniform progression, there being rather a sudden increase of brightness at about half its width. This inner edge is usually (not invariably) the brightest part of it, and it is sometimes comparable in brilliancy to the photosphere. (The general description just given applies only to the normal type of spots, and has very wide exceptions.) The penumbra is all but wholly made up, as it appears on a first examination, of cloud-forms whose structure makes them seem like fagots or sheaves of some elongated objects. These sheaves Mr. Dawes has compared to bundles of thatch, the likeness being helped by what appear to be individual straws protruding beyond others over the penumbral shade. With further study, with the highest powers, Mr. Dawes' comparison does not quite hold. With these the penumbra is resolved into "filaments" of extreme tenuity, which by their aggregation make the "thatch," just as the minute granules of the photosphere compose the "rice-grains." These filaments I have observed to have a tendency to lie in sheets or folds, whose superposition causes different degrees of brightness, and gives the thatch aspect (G_4 to H_7), and there is also a resemblance (not shown in the drawing) at times to the appearance of water falling so thickly that it coheres in sheets or veils, such as are seen, for instance, in advance of the main body of the fall at Niagara, or even at moments in violent rain storms.

In the best definition I find that the normal darkness of the outer penumbra is nothing else than the darkness of the gray medium in which the granules float all over the sun, though much deeper tints are here and there found, which sometimes make the penumbra almost resolvable into a ring of little spots. Over this shade stretch here and there bright filaments, which are continuous with the granules of the photosphere (K_3. F_6 to E_7 and elsewhere), *through* it are sometimes dimly traceable fila ments which apparently float at lower depths. It seems to me that there is no room for doubt, that "filaments" and "granules" are names for different aspects of the same thing; that filaments in reality are floating vertically all over the sun, their upper extremities appearing at the surface as granules; and that in the spots we only see the general structure of the photosphere, as if in section, owing to the filaments being here inclined. They are in the best definition very commonly observed to have a ragged outline near their extremities, like bearded grain, suggestive of the idea that they may be formed of the union of a still smaller order of their kind. They are not of strictly uniform size, but the larger ones usually give indications of resolvability.

It is practically impossible, in the brief intervals of perfect definition during which such work can be carried on, to so multiply micrometric measurements, that from their concordance any idea of their probable error is obtainable by the usual treatment. Measurements taken at different times, and on different parts of the penumbra, by counting the number of filaments in a given space, give from 0″·7 to 1″·0 as the average distance from center to center of parallel filaments separated by scarcely measurable intervals; at the same time that the distance in some places is greater, it is in others much less. One example of these measurements will suffice.

To reach a satisfactory determination of the upper limit of the size of these threads at their extremity, ten very close filaments were counted upon one occasion, which were separated by lines of unequal though not measurable width. Three consecutive measurements with the Filar micrometer gave 5″·34, 5″·30, 5″·27, as the width of the whole ten, the mean being 5″·30. To consider the effect of irradiation, we may assume from experience and without fear of contradiction, that a telescope of thirteen inches aperture, and with a power of 500, could not, under the most favorable circumstances, completely separate two stars whose distance is less than ″·3, and that considering that these vividly irradiant filaments were not only clearly separated, but that some of the divisions were wider than others, we must conclude that the unknown intervals which separate them are not *less* than ″·3. The sum of

the nine interspaces is then not less that 2″·7, and subtracting this from 5″·3 we have 2″·6, as the most that can be assigned to the ten filaments, giving 0″·26 as the upper limit for the width of those under examination. But filaments are sometimes visible on the umbra so attenuated that they seem like threads of gossamer, and which, if they have the same intrinsic brilliancy as those measured, are demonstrably not over ″·03 in diameter, and of course, apart from their irradiation, far beyond the reach of the most powerful telescope. Their appearance is somewhat rare, but I have studied it in several cases; between H_5–I_6 will be found an illustration, which, however, gives an inadequate idea of their extreme tenuity. One is reminded of recent spectroscopic drawings of filamentary structures in the chromosphere (*Comptes Rendus*, vol. lxxvi, p. 1054), though here the appearance is more tree-like.

The course of this examination has, it is hoped, made it plain, that if the photosphere were really composed of spindle-shaped bodies about one hundred miles wide by one thousand long (nearly 0″·2 by 2″,—the dimensions of Mr. Nasmyth's "willow-leaves"), they would not have escaped notice. Yet while, with a confidence justified by the micrometric measurements of so much smaller bodies, we may say that Mr. Nasmyth was misled in a matter of detail, we should remember that he appears to have been the first to distinctly call attention to the singular individuality of the minute components of the photosphere, and this seems in fairness to entitle him to the credit of an important discovery, with which his name should remain associated.

Solar cyclones, which, even without the aid of the spectroscope we see are incomparably more violent than our own tropical tornados, act on the filaments without destroying their identity. It is probable that both the filaments and the granules I have so minutely described, may hereafter be resolved into smaller components still, but their persistent individuality as a whole under such disturbance, impresses me as a most striking feature, and one for which, under similar circumstances we have no exact analogy in our own meteorology.*

Let us now consider the filaments as indices of the character of the gaseous circulation of the sun as we see it in the spots. We find about F_4 and G_3 two considerable masses of the pho-

* In the recent conclusions of Clerk Maxwell and others, as to the viscosity of gases under high temperature, and in what is known of the diffusion rates of gases and vapors, we have occasion for interesting suggestions as to the possible explanation of some of their peculiarities, the consideration of which, however, does not form a part of our present subject.

tosphere nearly severed from the main body by rifts which are spreading behind them, and which in the reality we should see progressively widening until these spaces were islanded, and merged in the penumbra. Immediately below them at H_3 commences a "bridge." It starts from the general level of the photosphere, which it apparently maintains throughout the entire length (of nearly 15,000 miles), as it is nearly equally brilliant everywhere. *The whole length is traversed by a fine line*, (this and the strange form of the extremity being sketched from one of two bridges in the great spot of September, 1870.) The theory of an eminent modern physicist, that sun-spots are solar clouds, and the bridges rifts in the cloud through which the photosphere is seen, would doubtless have been modified by an opportunity for personal observation of such details.

In this respect, these minutiæ are of interest, their study suggesting answers to many questions, and enabling us to decide in part as to opposed theories. Near I_3 the filaments are contorted and thrown over each other, a thing of ordinary occurrence. The row of brilliant dots immediately below this is an appearance which has not escaped Secchi, who has an illustration of it. Its physical interpretation has never, I think, been given; we obtain it in connection with the study of the filaments immediately below. The filaments in general wear the appearance of lying in sheets, or like feathers on a quill, but here the planes in which they lie are tilted vertically (by the action of an ascending current?) so as to expose the tips only which form the dots. Immediately below an instance is given of the effects of a current apparently setting upward and forming part of a whirlwind with an axis greatly inclined to the vertical, two successive laminæ of filaments being both curved and tilted. Following these filaments down to the umbra, we find them nearly uniformly curved, and just beyond them the umbra filled with brilliant points, on a ground less dark than the general shade. From this part of the spot (K_4 to J_6), every filament is copied, in exact collocution with its neighbors, from nature. We observe that their curvature increases rapidly toward their ends, and that those almost in contact may have their curves opposed. The physical explanation of this appears to involve the assumption of the presence of numerous small and independent whirlwinds; even right-handed and left-handed whirls being in juxtaposition. A strange kind of bar lay across the tips of the filaments here, in a position which could not have been anticipated. I have occasionally observed filaments stretching in masses over the umbra, which have a resemblance to reeds bending over a stream (I_6), some of them growing darker near the ends as if dipping their tips in its turbid fluid. A very peculiar form,

and one difficult of explanation at first, is that which I can best compare to the trunk of a fallen tree covered with snow, entirely smooth and straight upon one side, and hung with icicles on the other (I_6 to I_8).

In the spot whence this was taken, the appearance was so strikingly suggestive of crystalline structure, that it was necessary to recall that each "crystal" was from one to two thousand miles in length, to dispel the illusion. It is probably due to a rift in the photosphere (however caused), the filaments on opposing edges being partly drawn out and partly dissipated.

The appearance of the part of the spot just over this is inadequately represented in the sketch, and it would in fact be hard to depict it. Pine boughs covered with hoar-frost and icicles would not unfairly imitate its effect, for the impression derived in the polarizing eye-piece from the pure whiteness and the crystal-like forms of such portions is associated rather with cold than heat.

The umbra of a spot, as seen with this eye-piece, is a complex structure. The tips of the filaments, though usually bright as if turned up by an ascending current around the edges, are sometimes darker toward their extremities, as in an instance already cited (J_6); sometimes a whole bank of filaments appears submerged (I_4). Occasionally the bridges rise from below the photosphere, growing progressively brighter toward the extremity, as in a remarkable instance given in the sketch. The awkward termination of the bridge, bearing a certain rude resemblance to the outline of a human leg and foot, presents itself so often that I am inclined to attribute it to a constant cause.

It is a common thing to see a large spot built up by the adhesion of numerous groups of smaller ones. The appearance of these under low powers, is that of wholly isolated spots in accidental juxtaposition. Under closer scrutiny, however, they are seen to have a physical connection, denoted by faint outlines of cloud-forms of the photosphere, which unite them, and which take on the appearance of irregular *lines of rupture*, if I may use such an expression. (Several of these are given in the sketch, uniting the two main divisions of the drawing.) These lines of rupture are not always easily seen. They follow the irregular outline of the photospheric cloud-masses which determine them; frequently there is a uniform deeper shade at one side than another (G_{12} to I_{12}), and occasionally we make out that their course is bordered by an approximately horizontal disposition of the filaments like that seen in the penumbra. These ordinarily here show traces of cyclonic action. Incipient penumbræ they are, in fact, and the better our

definition the more clearly we see, that not only this, but every part of the photosphere, repeats with modifications the behavior of the larger penumbræ, so that we may almost say the sun at times seems to be *all spot.*

In the spot of March 5th, and in the portion indicated in the sketch, a long filament was seen bent into a curious ear-shaped curve. Before a rough sketch of it was completed, the whole of the northwestern part of the curve disappeared, being drawn away from the rest and dissolving as it moved, passing from white through shades of reddish brown till it was lost in the tints of the umbra. The portion which suffered this remarkable dissolution was about 3,000 miles in length. Clear evidence of superposed currents is seen where one stratum of filaments drifts over another in a different direction (H_4, I_{14} and elsewhere). This phenomenon has been apparently observed by Lockyer* and Secchi† in isolated cases. It seems to me clearly discernible almost everywhere, and that it is the indication of an important physical law of the gaseous circulation of the sun. We must infer from it that the circulation is not wholly in ascending and descending currents, or from uniform cyclonic action, but that currents greatly inclined to the vertical, and often approximately horizontal, are also everywhere superposed in the penumbræ; of which the photospheric clouds give ocular evidence of the same kind, and nearly the same conclusiveness that assures us of the different currents superposed in the terrestrial atmosphere.

In the northern portion of the same spot, which was the center of violent disturbance, several remarkable forms presented themselves, for the study of which I had the good fortune of excellent definition. The most prominent bore a resemblance in outline to a plume, but had something in its structure, I do not know how to render exactly, or to describe. The appearance of a window-pane covered with frost-figures would give a not inadequate idea of its effect, which was at once foliate and crystalline; but in the original this effect was also that of such a figure viewed through successive veils of lace, each superposing a semi-transparent and fern-like pattern. The whole appearance was one of singular beauty, and the sketch gives a most inadequate idea of it.

I use the terms "foliate" and "crystalline" as accurately descriptive of the appearance merely, without intending to apply them to the organic cause of the structure. Since writing this, I notice that the same dual comparison has presented itself to Secchi, who likens an appearance, which presented itself at the extremity of a "bridge," at once to that of a cactus and that of a crystallization of sal-ammoniac. (See Secchi–

* Monthly Notices Roy. Ast. Soc., 1865. † Die Sonne, vol. i, p. 86.

Schellen, Die Sonne, vol. i, p. 78.) Considering that this remarkable object covered a greater area than the united North and South American continents, it seems probable that the "crystalline" appearance was due, in part at least, to the superposition of the filaments in numerous semi-transparent cloud strata, and the lace-like veils to nearly transparent strata suspended still higher. "Clouds" is the only word we can employ, since we can only illustrate by terrestrial analysis, but the structure of the terrestrial cloud is formless and indefinite by comparison. The higher the telescopic power we can apply to such solar clouds, the more definite becomes the structure: we find everywhere those strange objects we call granules, or filaments, or crystals,* taking more varied and more definitely foliate forms the more we analyze them. I might borrow here from Mr. Lockyer his comparison of certain chromospheric forms to an English hedge-row. Some of the appearances of the chromosphere and photosphere seem almost identical: perhaps in looking through the former we receive at times a confused impression of its existence even without the spectroscope.

A reference to the drawing will show a curious structure, which was sketched at the same time. Lying upon the opposite side of the umbra were four long filaments, or fascicles of filaments, of immense size, bent into curves which, as they are typical ones, should be studied in their physical connection. I refer particularly to the "quickening" of the curves near their extremity, or, in other words, to the progressive rate of diminution of the radius of curvature throughout their entire length, as a probable index of the distance from the axis to the circumference of the cyclone which produced them. Connecting these curves with the opposite penumbra were several others, which joined them in the peculiar way shown ($C_{,5}$ to $C_{,6}$). These three were in the position of ropes made fast at both ends. [Notice the slight curve in each, the clear line on the concave, and the fringe on the convex side of the curve, as if it were blown out by the wind of the upper branch of the whirl.] Near the northwestern limits of the curve was a scene of violent disturbance. Even in the chaotic confusion here, it was noticeable that the filaments retained their individuality; far from blending into a common mist, they appeared here in short straight pieces as if broken. I say "as if," not meaning to predicate brittleness of their qualities, but at the same time asking attention to the appearance of these objects under such conditions, as one for which we could expect to find no good analogy in terrestrial clouds. Evidence of what appeared to be the meeting of right and left-handed whirls was not wanting in this part of the spot.

* A term already used by Chacornac.

It is very desirable to determine whether the penumbral slope is formed by a superior (or lateral) pressure which separates the photosphere, or whether it is built up by the deposits of vapors ascending from the sides of the umbra. I have made (B_{15}, B_{17}) a careful transcript from nature of every granule or filament visible in the penumbral edge for this distance. To me it seems that the edge of a torn piece of cloth, with its projecting threads, would not give clearer evidence of rupture.

I cannot conclude this description without speaking of the umbræ, though their study would form a chapter by itself. The polarizing eye-piece gives us interesting information about the nuclei or those darkish shades of the umbra discovered by Dawes.

Are these round, nearly central openings, so that looking into one we are looking into the axis of the cyclone to which the spot is due,—into the vortex of the great whirl *down* which the chromospheric vapors are being sucked by mechanical action? Are they ragged apertures—the craters as it were of eruptions whence metallic vapors are being forced *up?* The answer to this question, were there but these two alternatives, would be definitive as to our choice between the principal theories of solar circulation. But we cannot answer peremptorily in favor of either. I have seen these nuclei neatly defined, circular central apertures, but I have also and not unfrequently seen them ragged rents, as shown in the drawing. It is noticeable that the very darkest nuclei are sometimes close under the bright ends of filaments, which it would seem could not present their usual aspect with the downward suction of a cyclone beneath them.

I will briefly recapitulate those of the results of these telescopic studies which seem to have been before little observed or undescribed.

The ultimate visible constituents of the solar photosphere being, not the rice-grains, but smaller bodies which compose them, and the size of these latter being valuable at not over $0''{\cdot}3$; from a comparison of the total area covered by them with that of the whole sun, we are entitled to say that the greater part of the solar light comes from an area of not over one-fifth of its visible surface, and which may be indefinitely less.

We must then greatly increase our received estimates of the intensity of the action to which solar light (and presumptively its heat and actinism) are due, on whatever theory we form them. (There is a presumption from observation that there is a drift of all the photosphere in a direction approximately parallel to

its equator, while the evidence as to this point is not yet conclusive.)

In the penumbræ there are not only numerous small cyclones, and even right and left-handed whirls in the same spot, but probably currents ascending nearly vertically, while the action of superposed approximately horizontal currents is so general that they must be considered a prominent feature in our study of solar meteorology.

A study of the outer penumbral edge leads to the conclusion that it is formed by rupture.

Speaking without reference to spectroscopic investigations, it seems to me that we have in the behavior of our filaments a presumption as to the existence of ascending currents in the outer penumbra, and of both ascending and descending currents at the umbral edge; ascending ones being the more usual. I think I recognize with this, and very commonly, currents setting inward and upward from the outer confines of the spot, and I find no difficulty in associating the idea of these phenomena with that of cyclonic action. Let us remember that though the spot shown in our drawing is by no means one of the largest, the umbra of its left branch alone covers an area of over 100,000,000 English miles. If we keep the real vastness of the field of these operations before our minds, and use the terms in not too absolute a sense, we shall be able to see the truth of both the eruptive and cyclonic theories, in the coexistence of phenomena, which, discussed separately, would justify either.

It seems, however, hardly possible to devote long telescopic observation to the minute structure of the photosphere, without reaching the conclusion, that evidence of the cyclonic action is the more widely marked, and—while recognizing that the normal type of the cyclone-spot is rare, that the evidence of cyclonic action away from the spots is feeble, and that in them such action apparently does not explain all these phenomena—we yet cannot withhold a more or less complete acceptance of the theory of Faye, as one unquestionably resting upon a *vera causa*, and uniting beyond any other, a wide range of otherwise isolated truths under a single law.

Allegheny Observatory, Dec., 1873.

ART. XIV.—*Measurements of the Polarization of the Light reflected by the Sky, and by one or more plates of glass;* by Prof. EDWARD C. PICKERING.

THE following observations, which will be published in full in the Proceedings of the American Academy of Arts and Sciences, were conducted to test Fresnel's formula for the reflection of light. He showed that if the light was polarized in the plane of incidence, the amount reflected would be $A=\frac{\sin^2(i-r)}{\sin^2(i+r)}$, while, if polarized in a plane perpendicular to it, the proportion would be $B=\frac{\tan g^2(i-r)}{\tan g^2(i+r)}$, i and r representing the angles of incidence and refraction respectively. Natural light may be regarded as composed of two equal beams polarized at right angles, hence the amount reflected $R=\frac{1}{2}(A+B)=\frac{1}{2}\left(\frac{\sin^2(i-r)}{\sin^2(i+r)}+\frac{\tan g^2(i-r)}{\tan g^2(i+r)}\right)$, a formula which may be applied to any special case, by substituting proper values for i and r. The value of A evidently increases as i varies from 0° to 90°. That of B, on the other hand, diminishes from 0° until $i+r=90°$, when it equals 0, or at this angle, which is that of total polarization, all of the ray B is transmitted, all the reflected beam being polarized in the plane of incidence. When $i=90°$, $A=1$, $B=1$, hence all the light is reflected. When $i=0°$, A, B, and R equal $\left(\frac{n-1}{n+1}\right)^2$, hence the reflected light increases with n, being zero when $n=1$, and 100 per cent when $n=\infty$. Many familiar phenomena are thus readily accounted for. For instance, the brightness of the diamond, the covering power of white lead as a paint, and the brilliancy of wet or varnished stones and woods.

A curious case presents itself when $n=1+dn$ or differs from unity only by an infinitesimal amount. A then becomes equal to $\frac{1}{4}dn^2(1+\tan g^2 i)^2$, and $B=\frac{1}{4}dn^2(1-\tan g^2 i)^2$. When $i=0°$, A, B, and R equal $\frac{1}{4}dn^2$, and this quantity is accordingly taken as the unit in Table I. The first column gives various values of the angle of incidence, the second and third the corresponding values of A and B, the fourth the amount of light reflected, and the fifth the degree of polarization. The other columns will be explained hereafter. This table is evidently applicable to all cases where the media bounding the surface have nearly the same index, whether its absolute amount is great or small.

TABLE I.—Light reflected when n is near unity, or equals $1+dn$.

i	A	B	$\frac{1}{2}(A+B)$	$\frac{A-B}{A+B}$	Theor.	Obs.	Differ.
0°	1·000	1·000	1·000	0·0	0·0	0·0	0·0
5	1·015	·985	1·000	1·5	1·0	1·0	0·0
10	1·063	·939	1·001	6·2	4·2	3·5	+0·7
15	1·149	·862	1·005	14·3	10·0	9·0	+1·0
20	1·282	·752	1·017	26·0	18·2	17·5	+0·7
25	1·482	·612	1·047	41·5	29·0	28·5	+0·5
30	1·778	·444	1·111	60·0	42·0	41·0	+1·0
35	2·221	·260	1·240	79·1	55·4	56·0	−0·6
40	2·904	·088	1·496	94·5	66·1	67·0	−0·9
45	4·000	·000	2·000	100·0	70·0	72·0	−2·0
50	5·857	·176	3·016	94·5	66·1	68·0	−1·9
55	9·239	1·081	5·160	79·1	55·4	58·0	−2·6
60	16·000	4·000	10·000	60·0	42·0	44·0	−2·0
65	31·346	12·952	22·149	41·5	29·0	30·0	−1·0
70	73·079	42·884	57·981	26·0	18·2	18·0	+0·2
75	222·85	167·16	195·00	14·3	10·0	8·5	+1·5
80	1099·85	971·21	1035·53	6·2	4·2	3·0	+1·2
85	17330·64	16808·08	17069·36	1·5	1·0	1·0	0·0
90	∞	∞	∞	0·0	0·0	0·0	0·0

The most important application of Fresnel's formula is to the case of glass where n somewhat exceeds 1·5. The first portion of Table II. gives in an abreviated form the result of a computation, for various values of i, of A, B, R and the polarization of the reflected and refracted rays. When, as frequently happens in the case of plates of glass, the light passes through several parallel surfaces, a portion of the light reflected back by the second surface is again intercepted by the first surface. It may readily be proved that if A is the amount reflected by a single surface, the amount transmitted, including this internal reflection, will be $\frac{1-A}{1+(m-1)A}$, while if no internal reflection took place it would be only $(1-A)^m$. In Table II. the values of A, B, R and of the polarization, are given for 2, 8, and 20 surfaces, corresponding to 1, 4, and 10 plates of glass. In all these cases the index $n=1·55$.

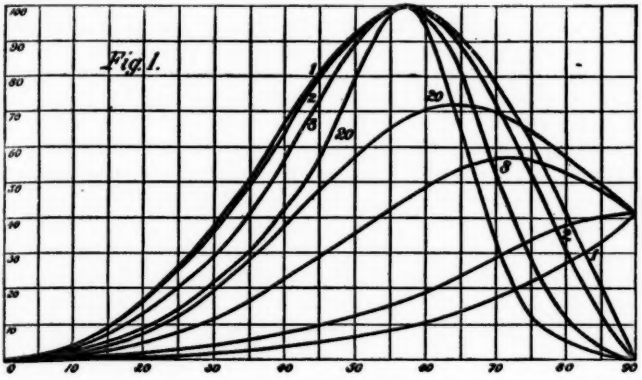
These results are perhaps better shown in figs. 1 and 2, in which abscissas represent values of i, and ordinates percentages of polarization.

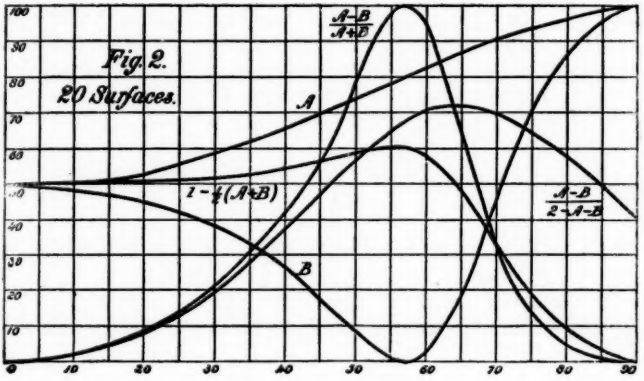
In fig. 1, the four highest curves represent the polarization of the beams reflected by 1, 2, 8, and 20 surfaces. The other four curves give the corresponding refracted beams. Fig. 2 gives all the curves of Table II, relating to twenty surfaces; the five curves corresponding to A, B, the intensity of the refracted beam, and the polarization of both the reflected and refracted beams. When $i=0$, both the reflected and refracted beams are unpolarized. With ten plates of glass about half the

TABLE II.—*Light reflected by* 1, 2, 8, *and* 20 *Surfaces.*

1 Surface.						2 Surfaces, 1 Plate.				
i	*A*	*B*	Reflect.	Per ct. Polariz. Reflect.	Refract.	*A*	*B*	Reflect.	Per ct. Polariz. Reflect.	Refract.
0°	4·6	4·6	4·6	0·0	0·0	8·8	8·8	8·8	0·0	0·0
5	4·7	4·6	4·6	1·0	0·0	9·0	8·7	8·8	1·0	0·1
10	4·8	4·5	4·7	4·0	0·2	9·2	8·6	8·9	4·1	0·4
15	5·1	4·2	4·7	9·1	0·4	9·8	8·1	8·9	9·2	0·9
20	5·4	3·9	4·7	16·4	0·8	10·4	7·5	8·9	16·3	1·6
25	5·9	3·5	4·7	25·9	1·3	11·1	6·7	8·9	25·4	2·5
30	6·6	3·0	4·8	37·8	1·9	12·5	5·8	9·1	36·4	3·6
35	7·5	2·4	5·0	51·7	2·7	14·2	4·7	9·4	49·3	5·2
40	8·8	1·7	5·3	66·7	3·7	16·4	3·5	10·0	64·0	7·2
45	10·4	1·1	5·7	81·2	4·9	19·0	2·1	10·6	80·1	9·4
50	12·5	0·5	6·5	92·9	6·5	22·4	0·5	11·4	95·6	12·5
55	15·4	0·1	7·7	99·3	8·3	26·9	0·1	14·0	99·3	15·6
57	17·0	0·0	8·5	100·0	9·3	29·1	0·0	14·5	100·0	17·0
60	19·3	0·1	9·7	98·8	10·6	32·4	0·2	16·3	98·8	19·2
65	24·7	1·1	12·9	91·2	13·5	38·4	2·5	20·4	87·7	23·2
70	32·0	4·0	18·0	77·7	17·1	48·5	7·7	28·1	72·6	28·4
75	42·0	10·4	26·2	61·8	21·9	59·6	19·7	39·1	52·2	33·2
80	55·7	23·3	39·5	41·0	26·8	71·7	38·0	54·8	30·7	37·2
82	62·6	31·6	47·1	32·8	29·3	77·1	48·3	62·7	22·7	38·6
84	70·3	42·4	56·3	24·7	32·1	82·7	60·2	71·4	15·7	39·6
85	74·5	49·0	61·8	20·6	33·3	85·4	68·5	75·8	12·6	40·0
86	79·0	56·6	67·2	16·5	34·8	88·2	72·5	80·3	9·8	40·4
87	83·8	65·3	74·6	12·4	36·3	91·4	79·2	85·3	7·0	40·8
88	88·9	75·3	82·1	8·2	37·9	94·1	86·1	90·1	4·4	41·0
89	94·3	86·8	90·5	4·1	39·6	96·9	92·9	94·9	2·0	41·1
90	100·0	100·0	100·0	0·0	41·2	100·0	100·0	100·0	0·0	41·2
	8 Surfaces, 4 Plates.					20 Surfaces, 10 Plates.				
0°	28·3	28·3	28·3	0·0	0·0	49·4	49·4	49·4	0·0	0·0
5	28·6	28·0	28·3	0·9	0·3	49·7	49·1	49·4	0·6	0·6
10	29·2	27·4	2	3·4	1·2	50·4	48·3	49·3	2·1	2·1
15	30·2	26·3	28·3	7·4	2·7	51·5	46·9	49·2	4·7	4·6
20	31·9	24·5	28·2	13·1	5·1	53·3	44·9	49·1	8·5	8·3
25	33·9	22·4	28·2	20·3	7·9	55·8	42·2	49·0	13·9	13·4
30	36·3	19·8	28·1	29·2	11·4	58·7	38·2	48·4	21·2	19·7
35	39·5	16·5	28·0	41·1	16·0	62·2	33·0	47·6	30·9	27·9
40	43·7	12.1	27·9	56·4	21·8	65·9	26·3	46·2	42·4	36·7
45	48·3	7·4	27·9	73·3	28·1	69·8	17·1	43·4	55·9	46·6
50	53·5	3·2	28·3	88·7	35·1	74·1	8·5	41·3	79·5	56·4
55	59·4	0·5	30·0	98·3	42·0	78·4	1·0	39·7	97·5	64·5
57	62·1	0·0	31·0	100·0	45·0	80·4	0·0	40·2	100·0	67·2
60	66·3	1·7	34·0	95·0	48·9	82·8	2·4	43·6	94·5	71·0
65	72·5	7·6	40·0	81·0	54·1	86·9	18·6	52·7	64·7	72·2
70	79·0	25·0	52·0	51·9	56·3	90·4	45·5	68·0	33·0	70·0
75	85·3	48·2	66·7	27·8	55·8	93·5	69·9	81·7	11·3	64·6
80	91·0	71·1	81·0	12·3	52·6	96·2	85·9	91·0	5 6	57·1
82	93·1	79·0	86·0	8·2	50·5	97·1	90·3	93·7	3·6	54·0
84	95·0	85·5	90·2	5·2	48·6	97·9	93·7	95·8	2·2	50·9
85	95·5	88·4	92·0	3·8	47·5	98·3	95·1	96·7	1·6	49·3
86	96·8	91·3	94·0	2·6	46·2	98·7	96·4	97·5	1·2	47·7
87	97·6	93·8	95·7	1·7	45·0	99·0	97·4	98·2	0·8	46·1
88	98·4	96·1	97·2	1·1	43·8	99·4	98·4	98·9	0·5	44·5
89	99·2	98·1	98·6	0·5	42·5	99·7	99·2	99·4	0·2	42·9
90	100·0	100.0	100·0	0·0	41·2	100·0	100·0	100·0	0·0	41·2

light is reflected, the transmitted ray being but little brighter than that reflected. With 1 or 2 surfaces the reflected beam





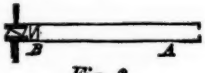


Fig. 3.

Fig. 4.

increases as i increases; with 8 surfaces it remains nearly constant up to 50°; while with 20 surfaces a marked diminution

is perceived. This very remarkable result may be expressed by saying that ten plates of glass transmit more light obliquely than normally. The appearance to the eye confirms this result, but it deserves a careful photometric proof. At 57° the reflected ray is, of course, in all cases, totally polarized; but at other angles the amount of polarization is greater the less the number of surfaces, instead of the contrary, as might have been anticipated.

With the refracted ray quite a different law holds. For one surface the polarization increases from 0° to 90°; with two surfaces it becomes sensibly constant near 90°; while with a larger number a distinct maximum is obtained. It is commonly supposed that the greatest effect is obtained at the angle of total polarization. But the maximum is sensibly beyond this, unless a very large number of plates is employed; and hence it seems probable that a bundle of plates, polarizing by refraction, would give the best results if set at a greater angle than 57°, as 65° or 70°. The transmitted ray, however, diminishes rapidly for large angles of incidence. A very large number of plates is required to render the polarization nearly complete, which accounts for the light always remaining when even the best polariscopes by refraction are crossed. At 90° all the refracted beams are polarized by the same amount of 41·2 per cent. Or, at grazing incidence, the amount of polarization is independent of the number of plates, one polarizing as completely as a hundred. This number 41·2 may be obtained as follows. Differentiate the value of A in terms of i and r, and make $i=90°$, when the refracted beam will equal $1-A=4 \tan r\, di=3{\cdot}376\, di$, since when $i=90°$, $r=40°\ 10'{\cdot}7$. In the same way $1-B=\frac{8}{\sin 2r}\, di=8{\cdot}115\, di$, and applying to them the formulæ for the polarization of the refracted beam, we find it equal to 41·2.

To show how far these effects are due to internal reflection, another table was computed by the formula $(1-a)^m$, or supposing that no internal reflection took place. A comparison showed that while the reflected beam is affected but little a great change takes place in the transmitted light. The results are shown by dotted lines in figs. 7, 8, and 10, and will be discussed below.

To test the above conclusions, two experimental methods may be employed. First, by means of a photometer, to determine the amount of light in any given case; and, secondly, by means of a polarimeter, to determine the percentage of polarization of the reflected and refracted rays. The latter method has been employed in the following experiments. The instrument commonly used to measure the amount of polarization

was invented by Arago, and is called a polarimeter. It consists of a Nicol's prism and Savart's plates, in front of which are several glass plates, free to turn, and carrying an index which moves over a graduated circle, thus showing the angle through which they have been rotated. The prism and plates form a Savart's polariscope, which gives colored bands with either light or dark center, according as the plane of the prism is parallel or perpendicular to the plane of polarization. When the plates are so placed that the light passes through them normally, they have no effect on it; but when turned, they polarize it in a plane parallel to the axis of rotation, and by an amount dependent on the angle. Let the instrument be so set that the axis of rotation shall be perpendicular to the plane of polarization, and the plates set at zero. The bands will then be visible, the center one being bright. As the plates are turned, the bands become fainter, until their polarization neutralizes that originally present in the beam; beyond this point the bands reappear dark-centered. The amount of polarization is thus readily determined, by turning the plates until the bands disappear, when the angle is reduced to percentages by means of a table. The difficulty of computing this table is, however, the real objection to the use of this instrument. It may be determined by the formulæ given in the first part of this paper, but it of course then fails to prove them. Moreover, no account is taken of imperfect transparency, dust on the surface, and other sources of error. An excellent way of forming this table experimentally is to view through the instrument a beam of light totally polarized. If now the plane of polarization of the beam is changed, the percentage of polarization will alter, being zero when it is inclined 45° to the axis of the plates, and wholly polarized at an angle of 0° or 90°. At any angle a, the beam may be regarded as composed of two, $\cos^2 a$ polarized vertically, $\sin^2 a$ polarized horizontally. The percentage of polarization will therefore equal $\frac{\cos^2 a - \sin^2 a}{\cos^2 a + \sin^2 a} = \cos 2a$, from which the polarization corresponding to any given angle is readily determined.

The result of such a comparison is given in Table III. Four series of observations were taken, from which curves were constructed as in fig. 8, with angles of incidence as abscissas and percentages of polarization as ordinates. A curve was next drawn, coinciding with them as nearly as possible, and its ordinates are given in Table III, column 3; the angles of incidence are given in the first column, and the theoretical polarization in the second column of the same table. Column 4 gives the differences, and from it we see that, while the agreement is very close between 0° and 60°, above this point a marked variation is perceptible. This deviation will be further discussed in connection with fig. 8.

TABLE III.—*Table for Arago's Polarimeter.*

i	Theoretical.	Empirical.	Difference.
0°	0·0	0·0	0.0
20	5·1	5·0	−0.1
30	11·4	13.0	+1·6
40	21·8	23.5	1·7
50	35·1	37.0	1·9
55	42·0	43.0	1·0
60	48·9	49.0	0·1
65	54.1	57.5	3·4
70	56.3	63.5	7·2
75	55.8	67.0	11·2
80	52.6	72.0	19·4

To avoid the defects of the above instrument, the following arrangement has been employed. A brass tube, *A B*, fig. 3, about a foot long, is closed at one end by a double image prism, *B*, and at the other by a rectangular aperture, *A*, of such a width that its two images, as in the Arago polariscope, shall be in contact, but not overlapping. To the prism is attached a Nicol's prism, free to turn, and carrying an index, moving over a graduated circle, which shows how far it has been rotated. The tube is then mounted, so that it can be set at any altitude or azimuth, or rotated around its own axis, and three graduated circles serve to measure these quantities. In the instrument as actually constructed (fig. 4), the whole is supported on an upright, which terminates below in a large screw, *C*, by which it may be attached to a post or tree, when used out of doors. A tube slips over this, which carries a cross-piece forming a T, and through the top of this passes the end of a second T, through the end of which the polarimeter slides. Three of these tubes are graduated to show the azimuth and altitude of the polarimeter tube, and the amount it is turned around its own axis.

The working of the instrument is as follows. If the Nicol's prism is removed, and the light is unpolarized, the two images of the aperture at the end will be equally brilliant. If now the Nicol's prism is replaced and turned, the images will vary in brightness, alternately disappearing as intervals of 90°. If the light is polarized, one image will in general be brighter than the other; but by turning the Nicol's prism, certain positions will always be found in which the two images will be equal. The percentage of polarization is then readily determined from the angle through which the prism has been turned. To determine the law which connects these two, let the plane of polarization be vertical, and the line of junction of the two images parallel to it. Then call A and B the brightness of the two images respectively, in which case the polarization $p = \frac{A-B}{A+B}$. If the

prism is turned through an angle v, one image will have a brightness $A \sin^2 v$, the other $B \cos^2 v$; and if they are equal, $A \sin^2 v = B \cos^2 v$, hence $p = \frac{\cos^2 v - \sin^2 v}{\cos^2 v + \sin^2 v} = \cos 2v$. The amount of polarization is then very simply found by turning the Nicol until the images are equal, then reading the angle, doubling it, and taking the cosine. Evidently there are four positions of equality of the image; and in the following experiments all four were observed, reading to tenths of a degree, and the mean taken. The results may be reduced by a table of natural cosines, first multiplying the angle by two. Evidently when the light is unpolarized the angle will be 45°; when totally polarized 0°. When the line of junction is inclined to the plane of polarization by an angle w, the observed polarization $p' = p \cos 2w$. This suggests a means of determining the direction of the plane of polarization. Make two observations of the amount of polarization, turning the polarimeter 45°. Then call p, p', p'', the true and the observed polarization in the two cases, and w the unknown angle between the line of junction in its first position and the plane of polarization. Having given p' and p'', we wish to determine p and w. Evidently $p' = p \cos 2w$, and $p'' = p \cos 2(45° - w) = p \sin 2w$. Taking their quotient gives $\text{tang } 2w = \frac{p'}{p''}$, and the sum of their squares gives $p = \sqrt{p'^2 + p''^2}$. This method, though elegant theoretically, does not appear very accurate practically, as the plane is more accurately determined by covering the end of the polarimeter with a cap containing a plate of selenite, thus converting it into an Arago's polariscope. Then turn the tube until the two images have precisely the same color, when their line of junction will be inclined 45° to the plane of polarization. The plane may also be determined, more easily but less accurately, by removing the Nicol's prism, turning the tube until the two images are equally bright, and adding 45° to the reading.

We next wish to determine the delicacy of this instrument in different parts of its scale. If the Nicol's prism is set at an angle v', differing slightly from its true value v, the brightness of the two images will be $A \sin^2 v'$ and $B \cos^2 v'$ respectively. Now it is commonly assumed that the difference in two such images will be perceptible, when the difference in brightness, divided by the brightness of either, equals a certain fraction $\frac{1}{a}$, in which a equals about 80. By differentiation it may be proved that the error in p or dp corresponding to any value of a is given by the formula $dp = \frac{1 - p^2}{2a}$, from which the error in

the result for any unobserved difference in brightness of the two images is readily determined.

If $p=0$, $dp=\frac{1}{2a}$, its greatest value, which diminishes as the polarization increases, becoming zero when $p=0$. Hence the greater the polarization, the more accurately it can be measured. If $a=80$, $dp=\frac{1}{160}$ for its greatest value; hence the instrument should always give results within two-thirds of 1 per cent. Observation, however, shows that the error is much greater, a difference in brightness of $\frac{1}{80}$ being by no means perceptible.

The first series of observations were made on the light of the sky. The instrument was screwed into a post and levelled, the altitude and azimuth of the sun taken, and the instrument then directed toward the points to be observed. Most of these were in the same vertical plane with the sun, so that it was only necessary to determine their altitudes. The line of junction was then brought parallel to the plane of polarization; that is, turned until it was vertical, since it then lay in the plane passing through the sun. The four positions of the Nicol's prism, in which the two images were equally bright, were then observed, reading the angles to tenths of a degree, and taking the mean. The percentage of polarization was finally obtained as described above. Eleven series of observations were taken, nine at Waterville, N. H., in a valley at a height of 1500 feet, surrounded by mountains 4000 feet high; the other two from the top of the Institute of Technology, Boston. It soon became evident that the polarization depended on the solar distance of the point under observation, and not on the altitude. This is well shown in fig. 5, in which abscissas give the solar distances, and ordinates the polarization of the observed points. The sun's altitude varied in these series from 0° to 68°.

Before discussing these observations further, it seemed desirable to determine the polarization of other parts of the atmosphere not lying in the same vertical plane with the sun. Moreover, as the polarization of points at equal distances from the sun should be compared, the polarimeter was so mounted that its principal axis would pass through the sun. The two graduated circles would then give solar distances, and the angle from the vertical plane through the sun, instead of altitudes and azimuths. The second of these angles will be called the meridian distance, and will be regarded as positive to the right, and negative to the left of the sun. Of course, the direction of the axis should continually change, so as to follow the sun; but as great accuracy in the determination of the angles was not needed, it was found sufficient to re-adjust it every few minutes. Another advantage of this arrangement was, that the line of junction, being turned parallel to the axis, would always lie in

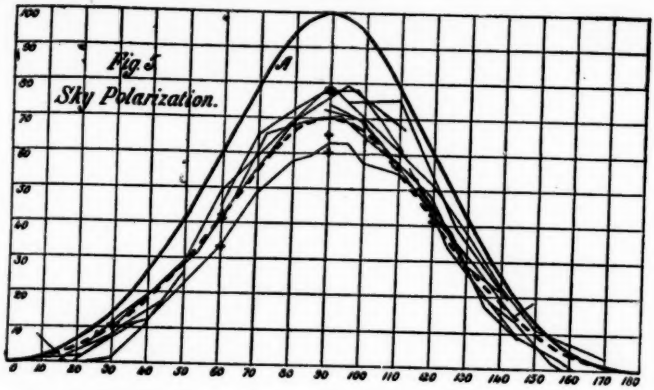


Fig 5
Sky Polarization.
A

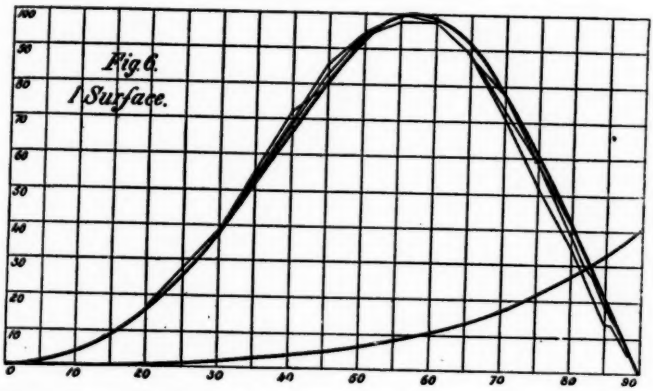


Fig 6.
1 Surface.

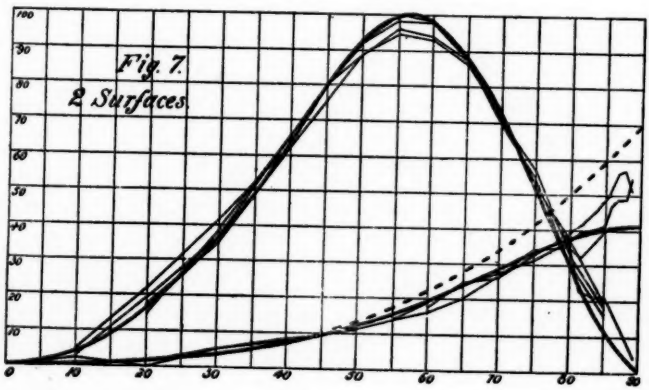


Fig. 7.
2 Surfaces

the plane passing through the sun, and hence be parallel to the plane of polarization. Five series of observations were made in this way, all tending to show that the polarization was independent of the distance of the point to the right or left of the plane passing through the sun. The results are given in Table IV, in which the first column gives the number of the series, the second the sun's altitude, the third its distance from the points observed, the fourth the number of the latter, and the fifth their mean polarization.

TABLE IV.—*Polarization of points equidistant from the sun.*

Series.	Alt.	Dist.	Theo.	Pol'n.
12	5°	90°	9	76·7
13	20°	60°	6	42·9
14	48°	90°	8	65·4
	45°	60°	10	41·7
	42°	120°	2	42·4
	40°	30°	8	10·7
15	40°	90°	10	60·4
	41°	120°	9	40·9
	43°	60°	10	34·2
16	−5°	90°	6	77·5

One series, the first, is given in full in Table V, to show the amount of variation of the different points observed.

TABLE V.—Series 12. July 15.
Sun's Distance 90°, Altitude 5°.

M. D.	Polar.
75	78·6
60	74·3
45	79·8
30	77·0
0	77·2
30	74·8
45	75·2
60	76·8
75	76·8
Mean	76·7

All these observations point to one very remarkable result; namely, that the polarization is the same for a given solar distance for any meridian distance; in other words, that the polarization is the same for all points equally distant from the sun. The variations in the observations are to be ascribed partly to errors of observation and partly to real irregularities in the atmosphere, as it is evident that they follow no regular law. The means therefore give us the true polarization with much greater accuracy. They are represented in fig. 5 by small crosses. The next thing is to determine the law which connects the polarization with the solar distance in all these

observations. A drawing was made like fig. 5 enlarged, and a fine copper wire laid on it, and bent into such a shape that it should coincide as nearly as possible with all the observations. The ordinates for every 10° were then read off, giving the results entered in column 7, headed Obs., of Table I.

A simple explanation of the polarization of the sky is to assume that it consists of molecules of air or aqueous vapor, which reflect the light specularly, and whose index of refraction differs only by a very minute amount from that of the medium in which they float. The theoretical polarization would then be at once given by Table I, making i equal to one-half the solar distance. The curve thus obtained is given in fig. 5, at A. The polarization according to this should be complete at 90° from the sun, while in reality it is only about 70 per cent. If, however, we multiply the ordinates of curve A by this fraction, we obtain curve B, which agrees almost precisely with the curve given in column 7 of Table I. Its ordinates are given in column 6, and the differences in column 8. From the latter it will be seen that the empirical curve gives results somewhat too great for solar distances less than 60°, and too small for greater distances; but the deviation is so small, compared with the accidental errors, that we are justified in regarding the agreement as complete within the limits of errors of observation. It will be noticed that no account is here taken of the points of no polarization, or neutral points of the sky; but the polarization is very slight for some distance from them, and hence is not easily measured. They must be regarded as due to some secondary disturbing cause, as refracted light, which alters the general polarization of the sky but little.

When the polarimeter is directed toward a polished colored plane surface, the two images assume different tints. One, which contains the light polarized in the plane of incidence, or B, is composed mainly of the light reflected specularly, and is therefore white like the source of light. The image A contains but little of the light reflected specularly, consisting principally of the rays emitted by the body, and hence partaking of its color. The idea at once suggested itself that testing the light of the sky in this way might give a clue to the cause of its color. The experiment was tried several times, with negative results, the two images appearing of precisely the same blue tint. But on the evening of July 15th, near sunset, when measuring the polarization of a point near the northern horizon, where the blue color was comparatively pale, a marked difference in the two images was observable. The image B was found to be of a yellowish brown, A of a grayish blue or violet tint. This observation has since been frequently repeated, and can, in fact, be made almost any clear evening near sunset.

Evidently we may conclude from these colors that the true color of the sky particles is blue, a view quite in accordance with the observations of Prof. Cooke with the spectroscope, and Prof. Tyndall on aqueous vapor in a state of formation.

Observations were next made to test the results formed above for the light reflected and transmitted by several parallel surfaces of glass. To check the results which are given in figs. 6–10, two, and in some cases three, independent methods were employed. To measure the polarization of the reflected ray, one or more sheets of glass were laid on a piece of black velvet and rendered horizontal with a spirit-level. The polarimeter was mounted a short distance from them, carefully levelled and turned down, so that the light should be reflected from their surfaces. Its angle of depression would then equal the complement of the angle of incidence. The line of junction of the two images was then rendered vertical, and the polarization measured in the usual way. The polarization of the sky, if clear, would introduce a large error into the results, and care was therefore taken to make these observations only on cloudy days. The second method was to replace the slit of a large Babinet's goniometer or optical circle by a Nicol's prism, which was free to turn around its axis, the angle of rotation being measured by a graduated circle and index. In the eye-piece of the observing telescope a Nicol's prism was placed, and in front of it quartz wedges giving lines, which were bright or dark-centered, according as the transmitted ray was polarized vertically or horizontally. On looking through the telescope, the field was seen to be traversed with lines, which disappeared only when the Nicol in the collimator was inclined 45° with the vertical. At any other angle, a, the vertical and horizontal components were $\cos^2 a$ and $\sin^2 a$, and hence were equivalent to a beam polarized vertically by an amount $\cos 2a$. If now any object was inserted between the two telescopes polarizing the light horizontally, p, the bands would disappear only when $p = \cos 2a$. Measuring the four positions of disappearance, and taking their mean, gave an accurate measure of the polarization by a table of natural cosines, as with the polarimeter described above. Another way of expressing the effect of this instrument is to say that the bands disappear when the Nicol is so turned that the plane of polarization shall be brought by the object under examination to an angle of 45°. The method of measuring the polarization of the reflected ray is now obvious. The pieces of glass are placed vertically on the center plate between the two telescopes, the latter set at an angle of $2i$, and the glass turned until the light is reflected from its surface, so as to render the field bright. The Nicol is then turned until the bands disappear, and its position recorded. The angle be-

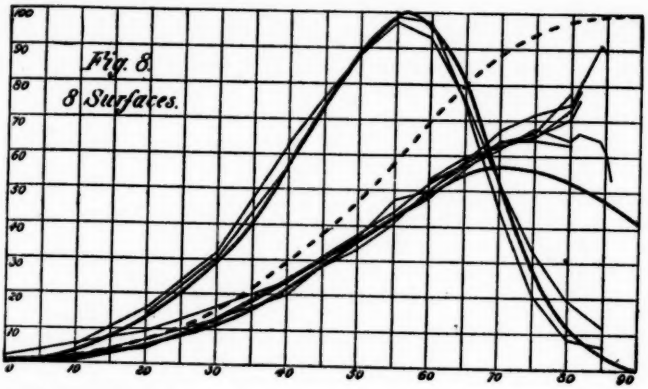


Fig. 8.
8 Surfaces.

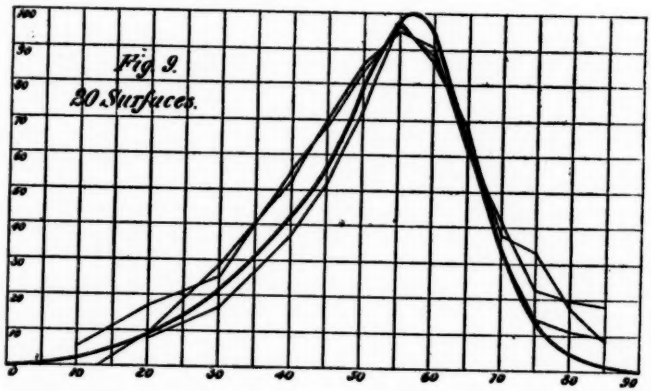


Fig. 9.
20 Surfaces.

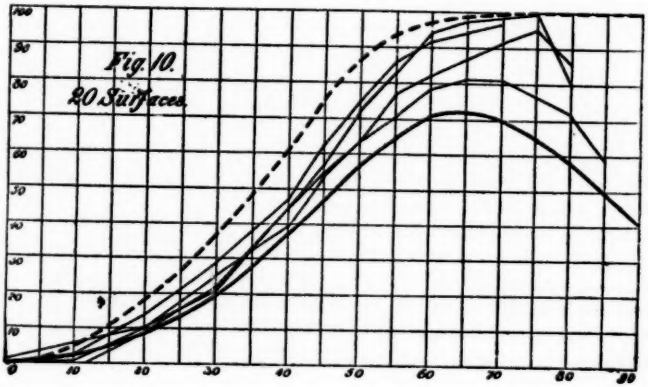


Fig. 10.
20 Surfaces.

tween the telescopes is then altered so as to make i successively 10°, 20°, 30°, &c., and the observation repeated. Various adjustments must be made to eliminate constant errors, but they need not be detailed here. One series was made with a glass prism having an index of 1·52, a second with a plate of colored glass, a third with a sheet of plate glass and others with four and ten microscope slides. The latter were used, as the thickness of the plate-glass was such that, when a number of plates were placed between the telescopes, a portion of the internal reflection would be lost.

To measure the polarization by refraction, two similar methods were employed. The plates were placed vertically over the center of a graduated circle, and a piece of ground-glass was viewed through them by the polarimeter. The plates were then set at various angles, and the polarization measured in each case. All these observations were made in cloudy weather, to eliminate the effect of sky polarization. Several series were made with the optical circle and Babinet's wedges, placing the telescopes opposite each other, and recording the angles of the Nicol for various positions of the plates. Still a third method was employed, already described in connection with the Arago's polarimeter.

It will be noticed that no observations are given of the polarization of a beam transmitted by one surface of glass. There seemed to be no easy method of measuring this quantity. It might be done by making a series of prisms of such angles that when the light was incident on one face at 10°, 20°, 30°, &c., the refracted ray would strike normally on the second face. The effect of the latter would then be nothing, so that the polarization would in this case be entirely due to the first surface.

To determine the polarization of a single surface of glass a plate was covered on one side with lamp-black, but it was found to give the same results as when laid on velvet. A plate of colored glass was therefore used instead. Fig. 6 gives the results of the observations of the polarization effected by one surface of glass, fig. 7, that of two surfaces, fig. 8, of four, fig. 9, the reflected beam for twenty surfaces, and fig. 10 the corresponding refracted beam. The smooth curves give the theoretical polarization, including the internal reflection, and the dotted lines omitting it. The observations of the reflected beam agree very well with theory, especially when the number of surfaces is small. The refracted beams, on the other hand, show a deviation from theory which becomes perceptible for one plate above 80°, for four plates above 65°, and for ten plates above 20°. The errors most likely to occur, which would be common to all the observations on the refracted beams, are, first, stray light, or light entering the instrument without passing through the

glass; secondly, light passing through the glass endwise, which might be recognized by its deep green color; and, thirdly, light reflected from the front surfaces of the plates. But all these errors would tend to diminish, instead of increase, the polarization; and hence, if eliminated, the divergence from theory would be still greater. Probably the true explanation is that internal reflection does not take place as completely as theory assumes, partly owing to the imperfect transparency of the medium, and partly to the dust and other impurities on the surface. It makes but little difference for the reflected rays, the polarization being the same for three values of i, namely, 0°, 57°, and 90°. For the refracted ray, on the other hand, the variations are very great, amounting in the case of twenty surfaces, at 90° incidence, to over 50 per cent. From the dotted lines we see that a partial absence of the internal reflection would account for all the results obtained, while neglecting it entirely would cause a still greater divergence between theory and observation.

On account of the thickness of the bundle of ten plates of glass, a portion of the secondary reflection would be thrown a considerable distance to one side, especially when i is large, so that it might fall quite outside of the instrument, or even be cut off by the ends of the plates. This effect would be least marked with the polarimeter, next with the Savart, and most of all with the optical circle, on account of the small aperture of the telescope. But this is just the order in which the observations stand, all of them falling between the two theoretical curves. These observations also show the effect to be expected from a bundle of plates when used to polarize light by refraction. If ten plates are employed, set, as is usual, at 57°, the polarization would be only 67·2 per cent if internal reflection takes place, but would be 95·2 if this is in any way excluded. We may, in passing, point out that an advantage might be expected in such a polariscope from an increase in the angle of incidence, the increased polarization probably more than making up for the loss of light and distortion induced by the increased obliquity of the incident rays.

The want of perfect transparency of the glass would also tend to increase the polarization by enfeebling the secondary reflection, and dirt or grease on the surface of the glass would produce the same effect. With eight and two surfaces, these disturbing causes are much less marked, except for large angles of incidence, and hence the agreement with theory much better.

ART. XV.—*On the Dissipation of Electricity in Gases;* by DEMETRIEFF BOBOULIEFF.

[Translated from the Journal of the Russian Chemical and Physical Societies, by CLEVELAND ABBE.]*

THERE are, according to the general statement, four forms of electrical discharge manifested in gases. Three of these are accompanied by luminous manifestations, and the sudden loss of electricity; these are the following:

1. Discharge as an electrical spark.
2. Discharge as a luminous sheet.
3. Discharge as a kind of diffused light (Glimmlicht).
4. A discharge without any light, and as a gradual slow loss; this latter case is called dissipation (rassyania, dêperdition, zerstreuung) of electricity.

Coulomb has paid special attention to this dissipation, and the circumstances affecting the investigation into the distribution of electricity on conducting bodies. He has given a formula expressing the connection between the quantities Q_0 and Q of electricity, found in a given body, at the beginning and the end of an interval, t, of time, during which the dissipation continues; which is

$$Q = Q_0 e^{-\frac{t}{2p}}. \tag{1}$$

The quantity $\frac{1}{p}$ is called the coefficient of dissipation; when it diminishes, i. e., when p increases, then the dissipation is slower, and *vice versa.*

Coulomb, making his observations in ordinary moist air, observed that the quantity $\frac{1}{p}$ was very changeable. This might arise from the changes of temperature or of atmospheric pressure, and the pressure of the aqueous vapor. Coulomb paid special attention to the action of aqueous vapor, and expressed his opinion that $\frac{1}{p}$ varies as the cube root of the quantity of vapor contained in a given volume of air. Many others after him have engaged in experiments to determine this connection between the coefficient of dissipation and all the above quoted causes; but the results of these labors harmonize but very little.

I give here, in consecutive order, the conclusions of all the following savants:—

* I have to acknowledge the assistance of Mr. H. Kalusoski in the preparation of this somewhat free translation of M. Boboulieff's interesting memoir.—C. A.

Matteuci: Memoire sur la propagation de l'électricité dans les corps isolants, solides et gazeux. Annales de Chimie et de Physique, 3me Serie, vol. xxviii, pp. 385–429.

Dellmann: Ueber die Gesetzmässigkeit und die Theorie des Electricitätsverlustes. Zeitschrift für die Mathematik und Physik, von Schlömilch, Kahl und Cantor, xi, 1866, pp. 325-354.

Charault: Recherches sur la dêperdition de l'électricité statique par l'air et les supports. Comptes Rendus, vol. l, pp. 108–111.

Warburg: Ueber die Zerstreuung der Elektricität in Gasen. Poggendorff's Annalen, B. cxlv, s. 578–599.*

1. *Of the Coulomb's Law expressed in the formula* (1).

Matteuci (p. 390) says: "The dissipation of electricity in pure and very dry air and gases† does not follow the formula and laws of Coulomb." He determined his law by experiments carried on in damp air; within certain limits, the dissipation is certainly not in proportion to the quantity of electricity "contained in the body."

Dellmann (p. 336): "The absolute dissipation is proportional to the density of the electricity; that is, it is according to Coulomb's law."

Charault: "The dissipation always follows Coulomb's law."

Warburg: "The dissipation of electricity in gases follows Coulomb's law."

2. *Influence of surrounding bodies.*

Matteuci (p. 389): The dissipation of the electricity depends upon the electric condition of the bodies found near the body under examination; the smallest loss is experienced when the neighboring bodies are charged with an electricity opposite to that in the body under examination.

Charault says: "The dissipation follows Coulomb's law in limited and unlimited spaces."

3. *The influence of the movement of the gases.*

Matteuci says (p. 386): "The dissipation does not increase when the air is in motion, but, on the contrary, it diminishes; and furthermore, this diminution is in proportion to the velocity of the movement of the air in relation to the body, and to the amount of the dissipation itself."

Dellmann (p. 345): "The dissipation does not depend on the motion of the air."

* Received in Russia while the author was engaged in making his own experiments on the subject.

† The electrical dissipation for an interval dt is, according to Coulomb's law,

$$dQ = -\frac{Q}{2p}\,dt.$$

4. *Influence of the size, configuration and conductibility of the body.*

Reiss* (pp. 111–113): "The dissipation does not depend on these circumstances."

Matteuci (p. 406): "The laws and the amount of the dissipation are independent of the matter of the bodies."

Dellmann (p. 344): "The dissipation does not depend on the size, form and matter of the electrified body." (p. 346): "The dissipation is the same in conductors and non-conductors."

5. *Influence of the kind of electricity.*

Biot, repeating Reiss's experiments, came to the same opinion,† "that the coefficient of dissipation does not depend on the sign of the electricity."

Matteuci (p. 408): "The dissipation and its laws are the same for both kinds of electricities, as well in dry gases as in the air; but in strongly charged bodies the negative electricity disappears much sooner."

Dellmann (p. 346): "The dissipation does not depend on the sign of the electricity."

Warburg (p. 599): "The dissipation of electricity of both signs is completed with the same rapidity."

6. *Influence of the temperature.*

Matteuci (p. 411): "In dry air the dissipation augments with increased temperature."

7. *Influence of humidity.*

Reiss‡ testifies: "That occasionally the dissipation diminishes with the increased dampness of the air."

Matteuci (p. 421): "In air of the same temperature, and under the same pressure, the dissipation increases with the quantity of suspended aqueous vapor; but this augmentation does not increase in proportion to the cube of the suspended vapors, as concluded by Coulomb from his too few experiments."

Dellmann (p. 541): "The dissipation does not depend on the percentage of moisture in the air, but on the quantity of the vapor included in one cubic foot of the air; and in proportion to the increase of this quantity, the dissipation increases."

Besides this, Dellmann adds: "that the dissipation is especially determined by the pressure of the aqueous vapor."

Charault says: "In dry air the coefficient of dissipation is very small compared with that for damp air. The coefficient increases with the increase of the dampness of the air, if the

* Die Lehre von der Reibungs electricität, Bd. i, s. 106–147.
† Riess, Bd. i, pp. 113–114.
‡ Reiss, Reibungs electricitat, p. 117.

quantity of vapor in the given volume remains the same. The coefficient of dissipation* increases with the increase of the quantity of vapor.

Warburg: "Damp air does not cause greater dissipation than dry air."

8. *Influence of the pressure.*

Matteuci (p. 415): "The quantity of electricity that may be retained on the surface of an isolated conductor depends on the density of the surrounding air. In a vacuum this quantity is nothing. The dissipation in dry air diminishes with the diminution of the density."

Warburg (p. 599): "The coefficient of dissipation sensibly diminishes when the pressure falls from 760^{mm} down to 380^{mm}, and at the pressure of 70^{mm} is less than one-third of what it was at 760^{mm}."

9. *Influence of various gases.*

Matteuci (p. 403): "In the air, hydrogen and carbonic acid, dry and pure, having the same pressure and temperature, the dissipation is the same."

Warburg: "Dissipation is the same in the air and carbonic acid, but in hydrogen one-half as great."

10. *Influence of tobacco smoke, etc.*

Dellmann (p. 346): "Dissipation diminishes in the presence of tobacco smoke."

Warburg (p. 594) supposes "that the hard particles floating in the air exercise some influence."

On my own part, on entering into the investigation of this same subject, relative to which I have quoted so many differing data, I was assisted by some theoretical conclusions which I think I can here explain.

Not only certain authorities in physical sciences, but even several specially devoted to electrical researches, sustain the view that electricity adheres only to the surface of conducting bodies by the counter-action or coöperation of the air in contact.† Such a theory would make us believe that in a vacuum the electricity meeting no force to oppose it would leave the surface of the electrified body, and would evaporate, as it were, in empty space until it extended to the walls of the enclosing cover or vessel, and subsequently be neutralized by contact with an electricity of an opposite sign. But many experiments

* Charault says, the dissipation in both cases decreases with the volume, thus:

$$a=\frac{1}{e^{2p}}.$$

† De la Rive, Traité de l'Electricité, T. i, p. 121.

tried at different times prove that gases even of the smallest density, and under the pressure of even less than 70^{mm}, can become under certain conditions conductors of electricity, and the first three of the above classes of electrical discharge may be observed through them;* but an absolute vacuum does not conduct electricity.†

On the other hand, it is impossible to deny all reaction on the part of the air, which is illustrated, for instance, by the movement of "Franklin's wheel."‡ But such a reaction may be derived from such atoms only as, after receiving electricity by contact with the electrified body, are repelled from it; of course, the magnitude of such reaction is very inconsiderable,§ but nevertheless it is accompanied by the other manifestation, that is, the loss of the electricity.

The atoms having received from the body a portion of its electricity, carry it away as they retire, and distribute it to other bodies, either electricized with an opposite electricity or having some direct connection with the earth. This constitutes in general the process of the loss of electricity by the agency of the gases, or the partial dissipation. Such, at least, is the opinion of almost all.‖ At present, when the new theory of the constitution of gases is accepted, such an explanation of the origin of electrical dissipation inspires hope that the subsequent development of electrical statics will aid in explaining the electrical manifestations observed in gases, and particularly the discharge of electricity, whether by sparks or by silent discharge; and the dependence of the electrical conductibility of the gases on the atmospheric pressure.

Accepting the hypothesis of atomic motions in gases, it will be easy to demonstrate that the dissipation of electricity depends on the pressure of the gas; and if we disregard certain circumstances we will find that,

1. Dissipation follows according to Coulomb's law.

2. The coefficient of dissipation, $\frac{1}{p}$, is inversely proportional to the square root of the absolute temperature of the gas.

3. That it is proportional to the pressure of the gas.

4. That it depends on the nature of the gas.

* Reiss, Reibungs electricität, B. i, pp. 39, 40; Morren, Pogg. Ann., B. 130, pp. 631, 633.

† Reiss, Rebungs electricität, B. i, pp. 39, 42; Alvergniat, C. R., Tome xlv, p. 963; Pogg. Ann., cxxxiii, p. 191; Wüllner, Pogg. Ann., cxxxiii, p. 509.

‡ In a vacuum this does not move.—Tomlinson, Phil. Mag. (4), xxvii.

§ Kötteritzsch attributes the amount of this reaction to a difference that exists between the results of the experiments of Harris and the computation of Thomson. —See Electrostatik von Kötteritsch, pp. 316–327.

‖ Reiss, Reibungs-electricität, vol. i, p. 108; Dellmann, Ueber die gesetzmässigkeit. . . . Zeitschrift f. Math., xi, pp. 348, 349; Matteuci, Memoire sur la propagation de l'electricité, Ann. de Chim. et de Phys. (3), T. xxvii, p. 171.

The new theory of the gases assumes that perfect gases are composed of atoms found in a state of perpetual motion. Each atom must be considered as a center of atomic force, whose tension diminishes in proportion to the separation of the atoms in such a manner that beyond the limits of a certain sphere the atomic force of the atom at its center becomes so insignificant that it can be considered to be nothing. This sphere is called the sphere of atomic action. The volume occupied by the sphere of any atom found in a given volume of gas is indefinitely small in comparison with the volume of the gas.

The motion of each atom is in a straight line and with a uniform velocity, and so continues as long as it does not bring the atom into contact with the sphere of another atom, or until one interferes with the action of the other; when this happens there results a change of motion of both atoms—a sort of concussion, after which each atom has a new direction and a new velocity. Such a concussion is similar to the striking of elastic balls, and is performed in an infinitely short time. The same thing is experienced in the concussion of particles or balls of any kind of hard bodies.*

If among such a collection of moving atoms there be placed an electrified body, the motion of all the atoms will change, because on each of them will operate a new force, the amount and direction of which will depend on the form of the electrified body, the quantity of its electricity, the distance of the atoms from its surface, and even the size of the atoms themselves; in general this force will attract the atoms to the body; but as these atoms are very small and the quantity of electricity in them almost nothing, therefore the force acting on the atoms will be very inconsiderable, and at a distance from the surface of the electrified body will be so insignificant that in the first moments of time the change in the motions will scarcely be marked, except for those atoms which come in contact with each other.

Let, for instance, the electrified body be a metallic ball whose radius $=R$; the quantity of its electricity $=Q$; each atom suffers an electrical induction depending on the action of the ball R, and the action of other neighboring bodies; omitting for the present the action of the last, we find that the force operating on the atoms (represented also by their radius$=r$) in the direction from the center of the atom to the center of the body, is equal to $\frac{dW}{dc}$ where†

* Clausius: Abhandlungen über die Mechanische Wärme Theorie, II, pp. 235, 261; Maxwell, Illustrations of the Dynamical Theory of Gases, Part I. Phil. Mag. (4), xix, pp. 19, 20.

† Considering the state of distribution of the electricity on two spheres under the influence of minute electrical forces.

$$(2) \qquad W = -\frac{Q^2}{2}\left\{\frac{1}{R} - \frac{r^2}{c^4}\right\},$$

and c is the distance between the centers of the ball and the atom; the equation (2) is obtained by disregarding higher powers of the fractions, as for instance $\frac{r}{c^2-R^2}$ and $\frac{rR}{c^2-R^2}$; which is allowable only in case $(c-R)$ is much greater than r.

Let us now see what will be the effect of such a force on the duration of the interval between two consecutive concussions. To this end let the velocities be u_0 and u; the distances of the center of the atom from the center of the electrified conductor at the beginning and the end of the interval be c_0 and c; then if we consider the living forces we find

$$u^2-u_0^2=\frac{Q^2r^2}{m}\left(\frac{1}{c^4}-\frac{1}{c_0^4}\right).$$

Let us put $c=c_0 \pm nl$ where $l=\frac{1}{1\,000\,000}$ of a millimeter, or the average length of the path between the concussions of two atoms;* and n is an abstract number of such value that the ratio $\frac{nl}{c}$ represents a small fraction, so that we can put

$$\frac{1}{c^4}-\frac{1}{c_0^4}=\pm\frac{4nl}{c_0^5};$$

thus we have

$$(3) \qquad u^2-u_0^2=\pm\frac{4Q^2r^2nl}{mc_0^5}.$$

The quantity m, the mass of the atom, can be expressed thus:

$$m=\frac{P}{Ng}=\frac{1}{Ng}\cdot\frac{\delta d H}{(1+\alpha t)760};$$

where P is the weight of the unit of volume of the gas; N is the number of atoms in said volume; $\delta=0{\cdot}001293$ milligram is the weight of one cubic millimeter of air at 0° C. and 760^{mm}; H is the actual pressure of the gas; t is the temperature; d is the density of the gas as compared with air; $g=9800^{mm}$ is the force of gravity expressed as a velocity per second.

Furthermore,†

$$N=\frac{1}{\lambda^3}=\frac{3}{4}\cdot\frac{1}{\pi\rho^3 l};$$

where λ is the mean distance between the atoms; ρ is the radius of action of the atoms. If now we indicate by $\Delta=\frac{Q}{4\pi R^2}$ the density of the electricity, i. e., the quantity belonging to one

* Clausius, Abhandlungen, II, p. 325.
† Clausius, Abhandlungen, II, p. 272.

square millimeter of the surface, then we will be able to write formula (3) in the following form:

$$u^2-u_0^2=\pm 48\pi\frac{R^4}{c_0^4}\cdot\frac{r^3}{c_0\rho^3}\cdot\frac{g760(1+\alpha t)}{\delta\cdot d\cdot H}\Delta^2 n=$$

$$\pm 1142927000\frac{R^4}{c_0^4}\cdot\frac{r^3}{c_0\rho^3}\cdot\frac{760(1+\alpha t)}{dH}\cdot\Delta^2 n.$$

To show how insignificant is the second part of this equation, we will make the following disadvantageous suppositions:

$$r=\frac{\rho}{10};\ \rho=\frac{l}{10^3};\ \text{where } r=\frac{1}{16\times 10^7};\ c_0=R;$$

and lastly, if for simplicity we put $t=0$, $H=760^{mm}$, $d=1$, for which there results* $u_0=485\times 10^3$ millimeters, we obtain

$$u^2=u_0^2\left(1\pm\frac{\Delta^2 n}{R}\cdot\frac{311}{10^{15}}\right)$$

or

$$u=u_0\left(1\pm\frac{\Delta^2 n}{R}\cdot\frac{155}{10^{15}}\right).$$

If we put $R=10^{mm}$, $\Delta=10^3$, $n=10^5$, which correspond well to a very strong tension of the electricity† and to a length of the path nl of six millimeters, we then obtain

$$\frac{u}{u_0}=1+0{\cdot}00155.$$

This change in the velocities will correspond to a change in the temperature of 0°·8 C. It follows that during the first moments there will fall on the surface of the electrified body—

1. Such atoms as would fall on it in case it were not electrified, and in consequence of gravity alone.
2. Such as are very near to the surface.
3. Such as may from greater or less distances accidentally pursue their paths past each other without concussion.

After the first moment, during which the falling atoms become electrized, they retire from the surface of the body and meet the non-electrized atoms, and communicate to the latter a part of the electricity received from the body; hence many atoms will remain at the surface of the body, and they will be charged with the same kind of electricity. The force acting on such atoms will direct them *from* the surface of the body, while the force acting on the neutralized atoms will attract them *toward* its surface: the former will diminish the number of atoms falling toward the body; the latter will increase that number.

* Clausius, Abhandlungen, II, p. 255.

† Compare Weber and Kohlrausch, Maassbestimmungen, Zurückführung der Stromintensitäts Messungen auf Mechanisches Maass., p. 263.

As the result of these considerations we must admit that *during the slow dissipation of the electricity the number of atoms dropping on the surface of the electrified body is nearly such as is determined by the pressure and temperature of the gas found nearest to the surface.*

According to Maxwell* the number of atoms adhering in a given unit of time to a given unit of surface is

$$\int_0^\infty dn \int_0^n \frac{nl-z}{2nl} \cdot \frac{Nu}{l} \cdot e^{-n} dz = \frac{Nu}{4};$$

where l and u are respectively the mean length of path and the mean velocity of the atom; N is the number of atoms in the unit of volume of the gas; z is the coördinate whose axis is normal to the surface; n, an abstract number, either whole or fractional, included between zero and infinity.

The number of atoms falling in the elementary space of time dt on the element ds of the surface of the body will be

$$\frac{Nu}{4} ds\, dt;$$

hence the number of atoms dropping in the time dt on the whole surface of the sphere R will be

$$\pi N u R^2 dt.$$

Each atom on striking the sphere will receive a quantity g of electricity, expressed by the equation†

$$g = \frac{\pi^2}{6} \cdot Q \frac{r^2}{R^2};$$

consequently the ball in the time dt will lose a quantity of electricity equal to

$$\frac{\pi^3}{6} N u Q r^2 dt;$$

that is to say,

$$dQ = -\frac{\pi^3}{6} N u Q r^2 dt;$$

whence, assuming N and u to be constant, we obtain by integration the formula of Coulomb:

$$Q = Q_0 e^{-\frac{t}{2p}};$$

in which the coefficient of dissipation will be

$$\frac{1}{p} = \frac{\pi^3}{3} N u r^2.$$

* Maxwell, Illustrations, Phil. Mag., vol. xix, p. 29.
† Reiss, Reibungs electricitat, vol. i, p. 226.

In order to demonstrate the dependence of this expression on the pressure of the gas, we will make use of the following:*

$$u=485\times10^3\sqrt{\frac{1+\alpha t}{d}};\qquad \mathrm{N}m=\frac{\delta d\mathrm{H}}{g\cdot760\cdot(1+\alpha t)},$$

where the letters have the same meaning as before; we then obtain:

$$(4)\qquad \frac{1}{p}=\frac{\pi^3}{3}\cdot\frac{\delta}{g}\cdot485\cdot10^3\cdot\frac{r^2}{m}\cdot\frac{\mathrm{H}}{760}\cdot\sqrt{\frac{d}{1+\alpha t}},$$

that is to say, the coefficient of dissipation in one and the same gas increases in proportion to the pressure.

Taking this conclusion for my base,† I undertook to investigate experimentally the dependence of the coefficient of dissipation on the pressure and properties of the gas. The apparatus that I used was constructed in the following manner:

On the copper plate of an air pump was fixed a bell glass, with an opening in its upper part. Into this opening a diaphragm was adapted, having a sliding tube plastered carefully, through which passed a copper rod, having at its upper end a glass handle, and at its lower end a curved prolongation ending with a small sphere. To the diaphragm there was attached a silk thread, from which hung by the middle a little bar (MN) made of shellac, about 100^{mm} long and 1^{mm} diameter, having on one of its ends a little ball made of elder pith covered with gold leaf, and on the other a small leaf of mica; by the middle of this bar again was fixed, also of shellac, a little rod 40^{mm} long and 2^{mm} diameter, carrying at its lower end a short magnetized needle. (*mn*). The ball was immovable, and of the same diameter as the movable one. On the outside of the bell glass on a level with the bar was pasted a scale (BB) on thin paper, divided on both sides into degrees. The position of the bar was observed from a distance of 1·5 meters from the bell glass by bringing the eye into a line with the silk thread and the corner of the mica sheet.

The air or gases were introduced into the bell glass through five drying tubes, of which one was filled with small pieces of pumice stone, wetted with sulphuric acid, and another with chloride of calcium; under the bell glass stood a small vessel containing pieces of phosphoric acid. The experiments were performed only after the bell glass had been at least three times refilled with such air or gas.

The shaft or copper rod served to charge the balls, which before being charged touched each other; in this position the

* Clausius, Abhandlungen, II, p. 255.

† Dellmann comes to the same conclusions as to the quantity of water in the air. Zeitschrift für die Mathematik und Physik v. Schlömilch. Band xl, s. 348–352.

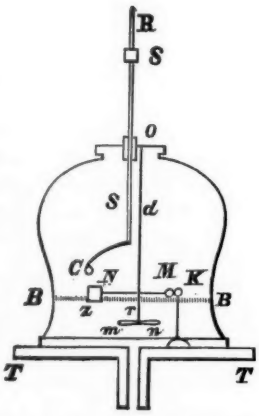
bar which supported the needle was in the magnetic meridian. When the balls are each charged with the same quantity of electricity, the bar MN will deviate by the angle a_0; then the moment of the repulsion of the electrical forces may be expressed thus:

$$\frac{Q^2}{4L^2 \sin^2 \frac{1}{2}a_0} L \cos \tfrac{1}{2}a_0;$$

and the moment of the magnetic force,

$$MT \sin a_0,$$

where L is the half length of the bar; M the magnetic moment of the needle *mn*, and T the intensity of terrestrial magnetism. Equating both expressions we obtain:



$$(5) \qquad Q_0^2 = 8MTL \sin^2 \tfrac{1}{2}a_0.$$

After the lapse of the time *t*, the quantity of electricity will become Q, and the angle of deviation will be *a*:

$$(6) \qquad Q^2 = 8MTL \sin^2 \tfrac{1}{2}a.$$

Eliminating the quantities Q and Q_0 from the equations (1), (5) and (6), we obtain:

$$(7) \qquad p = \frac{t \log e}{3(\log \sin \frac{1}{2}a_0 - \log \sin \frac{1}{2}a)}.$$

According to this formula I have computed *p*.

I am certain that each time I read the divisions on the paper scale BB, I could not make an error greater than one-half of a degree. The angle a_0 or *a* is the mean of four observed numbers; if in the neutral state of the balls I read the divisions X and X_1, and when they were electrified, the divisions Y and Y_1, then *a* is equal the half sum of the differences $X-Y$ and X_1-Y_1. In each of these four readings I could not commit an error of one-half of a degree; consequently the largest error in the determination of the angles $\frac{a}{2}$ and $\frac{a_0}{2}$ could amount only to $\frac{4}{4} \cdot \frac{1^\circ}{2} = \frac{1^\circ}{2}$.

If $\frac{1}{2}a$ and $\frac{1}{2}a_0$ be varied $\pm 30'$, then the log sin $\frac{1}{2}a_0$ and log sin $\frac{1}{2}a$ will vary, which I indicate thus:

$$\Delta \log \sin \tfrac{1}{2}a_0 \text{ and } \Delta \log \sin \tfrac{1}{2}a;$$

as a consequence of this, *p* will change to Δp; and we have

$$\frac{p+\Delta p}{p}=\frac{\log\sin\frac{a_0}{2}-\log\sin\frac{a}{2}}{\log\sin\frac{a_0}{2}-\log\sin\frac{a}{2}+\Delta\log\sin\frac{a_0}{2}-\Delta\log\sin\frac{a}{2}}$$

from this we obtain:

$$\frac{\Delta p}{p}=-\left\{\frac{\Delta\log\sin\frac{a_0}{2}-\Delta\log\sin\frac{a}{2}}{\log\sin\frac{a_0}{2}-\log\sin\frac{a}{2}}\right\}+\ldots.$$

where we see that the term expressed in the parenthesis is less than unity.

In the worst case, when $\Delta\log\sin\frac{a_0}{2}$ and $\Delta\log\sin\frac{a}{2}$ have opposite signs, we have for the greatest value of $\frac{\Delta p}{p}$

$$(8)\qquad \frac{\Delta p}{p}=\pm\frac{\Delta\log\sin\frac{a_0}{2}+\Delta\log\sin\frac{a}{2}}{\log\sin\frac{a_0}{2}-\log\sin\frac{a}{2}}$$

According to this formula I have computed the greatest possible error in the determination of the quantity p in my experiments; and have selected only those results in which $\frac{\Delta p}{p}$ is not more than 0·3: the rest I have rejected.

The electrical condition was maintained from eight to ten days, as for instance, from 30th June to 10th July, and in another case from 22nd June to 30th June.

The following are the results obtained:

I. *In dry air at the ordinary pressure.*

No.	Month.	Day.	Hour. P. M.	t	$\frac{a_0}{2}$ or $\frac{a}{2}$	$\frac{\Delta p}{p}$	p
1	July	12	1h 38m	----	7° 15′	----	----
	"	12	7 20	342m	2 45	0·2	118
2	"	20	7 57	----	20 52·5	----	----
	"	21	1 40	1063	4 52·5	0·08	247
	"	21	3 37	1180	2 7·5	0·09	174
3	August	14	1 15	----	19 0	----	----
	"	14	3 34	139	15 30	0·28	238
	"	14	4 2	167	15 7·5	0·25	251
4	"	18	4 38	----	19 30	----	----
	"	18	7 5	147	13 45	0·17	144

II. *In dry hydrogen under the ordinary pressure.*

No.	Month.	Day.	Hour. P. M.	t	$\frac{a_0}{2}$ or $\frac{a}{2}$	$\frac{\Delta p}{p}$	p
1	July	13	4h 30m	----	13° 0′	----	----
	"	14	1 0	1230m	7 30	0·17	753
2	"	22	3 40	----	17 30	----	----
	"	23	12 50	1270	12 0	0·18	1147
	"	23	3 10	1410	11 15	0·16	1086
	"	23	6 37	1617	10 15	0·14	1027
	"	24	12 27	2693	3 22·5	0·10	542
3	"	26	2 25	----	14 7·5	----	----
	"	26	8 3	458	11 22·5	0·35	716

III. *In dry air at pressures between* 24^{mm} *and* 50^{mm}.

No.	Month.	Day.	Hour. P. M.	t	$\frac{a_0}{2}$ or $\frac{a}{2}$	$\frac{\Delta p}{p}$	p	Pressure.
1	June	30	4h 0m	----	12° 30′	----	----	24mm
	July	1	4 0	1440m	9 15	0·3	1613	--
	"	2	1 30	2730	8 22·5	0·24	2297	--
	"	3	12 45	4125	7 15	0·18	2549	--
	"	4	2 10	5650	6 22·5	0·17	2822	25
	"	5	1 0 P.M.	7020	5 7·5	0·14	2644	--
	"	6	11 40 A.M.	8380	4 7·5	0·13	2536	28
	"	7	12 30 P.M.	9870	2 37·5	0·14	2118	32
	"	8	1 15	11355	1 45	0·15	1933	34
2	"	29	2 0	----	6 45	----	----	25
	"	30	2 46	1486	3 52·5	0·3	895	45
3	August	5	4 1	----	13 30	----	----	23
	"	6	1 4	1263	8 7·5	0·2	879	55
4	"	7	2 42	----	16 7·5	----	----	48
	"	8	12 57	1335	10 45	0·18	1117	55
	"	9	1 9	2787	5 52·5	0·1	937	65
5	"	15	4 33	----	15 30	----	----	34
	"	16	3 13	1360	10 52·5	0·2	1302	40
	"	17	2 34	2761	7 37·5	0·13	1312	45
	"	18	3 15	4242	3 52·5	0·11	1028	50
6	"	19	2 30	----	13 0	----	----	34
	"	20	6 6	1356	9 0	0·2	1244	35

The mean of Series

I, Air under pressure of 760^{mm}, $p=210$

II, Hydrogen under pressure of 760^{mm}, $p=878$

III, Air under pressure of $30–50^{mm}$, $p=1700$

I conclude from this:

1. That the dissipation of electricity in air (and other gases) diminishes with the diminution of the pressure.

2. That the dissipation in hydrogen is less than in air [at the same pressure].

ART. XVI.—*Brief Contributions to Zoölogy from the Museum of Yale College.* No. XXVII.—*Results of recent Dredging Expeditions on the Coast of New England.* No. 5; by A. E. VERRILL.

[Continued from page 46.]

THE shores of the islands and of Cape Elizabeth afford excellent collecting grounds at low water, owing to their diversified character. A large part of these shores are abrupt and rocky, and often formed of broken and precipitous ledges of hard metamorphic slates and thin-bedded grits, or altered sandstones, in some places passing into gneissose rocks, and generally dipping at a high angle. Tide-pools are of frequent occurrence, and often of large size, and afford excellent opportunities for obtaining the shallow-water and littoral species of animals, and many beautiful algæ. One very large pool on Ram Island Ledges was especially rich, and was visited several times with profit. In this pool young lobsters of all sizes were very abundant beneath the stones. Two species of Chitonidæ also occurred here, together with many other species not usually to be found at low-water mark. Hydroids and Bryozoa, of many species, were abundant in this and other similar pools. The shore species obtained upon the islands and outer shores of the bay were nearly all boreal or arctic forms. In the harbor of Portland, on the piles of the wharves, etc., a few more southern species were met with, though the northern ones predominate even there.

Several insects were met with between tides. Among these were *Chironomus oceanicus*, and the larvæ, about two inches long, of a fly, probably an *Eristalis*, which lived in small tide-pools, under stones, and extended their long tapering tails up to the surface; the pupa of a fly allied to *Ephydra;* a species of *Bledius*, and several other beetles; and two or three species of mites, were also collected between tides. The following were among the shore-dwelling species:

Crustacea.

Cancer borealis.	Gammarus marinus.	Cerapus rubricornis.
C. irroratus.	Hyale littoralis.	Unciola irrorata.
Hippolyte pusiola.	Talorchestia megalophthalma Smith.	Jæra copiosa.
H. spina.	Orchestia agilis Smith.	Idotea irrorata.
Crangon vulgaris.	Calliopius læviusculus.	I. phosphorea Harger.
Eupagurus Bernhardus.	Pontagenia inermis.	Erichsonia filiformis Harger.
E. Kroyeri.	Amathella angulosa (?).	Balanus balanoides.
Gammarus ornatus.		

Annelids.

Lepidonotus squamatus.	Nephthys, sp.	Eulalia pistacia V.
Harmothoë imbricata.	Nereis virens.	Eteone, sp.
Eunoë Œrstedii.	N. pelagica.	Phyllodoce catenula V.

Rhynchobolus dibranchiatus.	Autolytus cornutus.	Amphitrite brunnea (St. sp.).
Cirratulus cirratus.	Proceræa gracilis, new sp.†	Polycirrus, sp.
Lumbriconereis fragilis.	Polydora, sp.	Myxicola Steenstrupii.
Stephanosyllis ornata V., new sp.*	Nicomache, sp.	Fabricia Leidyi V.
	Clymenella torquata V.	Potamilla oculifera V.
	Cistenides granulatus.	Spirorbis borealis.

Turbellaria.

Nemertes viridis.	Cosmocephala Stimpsonii V.	Fovia affinis.
Borlasia, sp.	Monotus spatulicauda.	Leptoplana ellipsoides, etc.
Tetrastemma, three sp.	Monocelis, sp.	

Mollusca.

The shore Mollusca were decidedly northern, and the species were not very numerous. Among the most abundant of them are the following:

Purpura lapillus.	Littorina palliata.	Saxicava arctica.
Buccinum undatum.	Lacuna vincta.	Mya arenaria.
Ilyanassa obsoleta.	Rissoa aculeus.	Macoma fragilis.
Tritia trivittata.	Littorinella minuta St.	Turtonia minuta.
Lunatia heros.	Skenea planorbis.	Mytilus edulis.
Littorina littorea.	Acmæa testudinalis.	Modiola modiolus.
L. rudis.	Æolis papillosa.	Amarœcium glabrum.

* *Stephanosyllis ornata* V., sp. nov.

Body moderately slender, thickest near the middle, tapering slightly anteriorly, and rapidly posteriorly, the caudal portion acuminate, with two slender caudal cirri. Antennæ and tentacular-cirri long, slender, and tapering, slightly and irregularly annulated, or transversely wrinkled; median antenna longest, reaching back to about the tenth segment; lateral antennæ about equal to the upper tentacular cirrus, or reaching to about the sixth body-segment; lower cirrus about half as long; dorsal cirrus of the second segment very long and slender, equaling or exceeding the median antenna; dorsal cirri of the third segment as long as those of the first, or longer, more than twice the diameter of the body; those of the fourth segment less than half as long; those farther back unequal in length. Head rounded in front and behind, broad, the anterior pair of eyes larger and wider apart than the posterior ones; "epaulets" conspicuous, lanceolate, extending back to the fourth segment. Color, in life, pale green, especially beneath and on the sides above; back, bright orange-red, with transverse lines of green at the articulations; setigerous lobes whitish; lateral cirri pale greenish white; antennæ and tentacular-cirri pale salmon, often tipped with pink; epaulets orange, centered with green, and bordered by a line of white, and with a red line along the edge; head pale yellow; eyes black. Length, 12^{mm}; breadth, ·75^{mm}.

Casco Bay, 6 to 20 fathoms, stony; and in tide-pools at low-water. This was mentioned in No. xxvi, p. 43, as "*S. picta;*" that name is preoccupied.

† *Proceræa gracilis* V., sp. nov.

Body very slender, elongated. Head subcordate, longer than broad, rounded in front, posteriorly extending back in two short rounded lobes, not reaching beyond the buccal segment; anterior eyes considerably farther apart than the posterior ones. Antennæ and upper cirri of the first two segments very long and slender, faintly annulated; the median antenna is very much elongated, considerably longer than the lateral ones, and about equal to the dorsal cirri of the second segment; the lateral antennæ are about as long as the upper tentacular-cirri, or about five times the diameter of the body; the dorsal cirri of the third segment are about twice as long as the diameter of the body; the cirri on the succeeding segments are about half as long as the breadth of the body. Color, in life, pale greenish, with a narrow median dorsal line of dark brown, and a less distinct one on each side, at the base of the lateral appendages; eyes black. Length, about 25^{mm}; breadth, 1^{mm}, or less.

Casco Bay, 10 to 20 fathoms; and in tide-pools.

Radiata.

The most common shore species were:

Strongylocentrotus Drö-bachiensis.	Campanularia flexuosa.	Sertularella rugosa.
Asterias vulgaris.	Sertularia pumila.	Clava leptostyla.
Obelia geniculata.	S. argentea.	Metridium marginatum.

Several species of sponges are also common between tides.

On the sheltered muddy bottoms, from just below low-water mark, to the depth of about two fathoms, the eel-grass, *Zostera marina*, grows in abundance. Among this many species of crustacea, worms, and mollusks find congenial abodes, and furnish abundant food for the fishes that frequent such localities. Some of these are somewhat southern in character.

Among the Crustacea from the eel-grass were: *Hippolyte Gaimardii; Crangon vulgaris; Mysis stenolepsis* Smith; *M. Americana* Smith; *Calliopius læviusculus;* a new genus with very large epimera, allied to *Metopa;* a new species of *Munna*, a genus of isopod crustacea, new to the American coast; *Idotea irrorata*, etc.

From the piles of the wharves at Portland a great variety of sponges, hydroids, bryozoa, etc., were obtained; the slender branched sponge, *Chalina oculata*, was here particularly abundant and fine; also *Metridium marginatum;* and the compound Ascidian, *Amarœcium glabrum* V., with many other northern forms. The *Limnoria lignorum* was found in abundance, destroying the piles and timbers.

Among the more interesting littoral species obtained on the shores of Casco Bay and vicinity, were *Littorina littorea* and the *Cancer borealis.* The latter is a large crab which has hitherto been very rare in all collections, and but imperfectly known; this we found in large numbers on the ledges at the northern end of Peak's Island and Pumpkin Knob, in tide-pools, or clinging to the sea-weeds in more exposed situations, but never concealed beneath the rocks with the *Cancer irroratus*, which was there abundant. The carapaces and claws of the former were also found in abundance at considerable distances from the shores, whither they had been carried by the gulls and crows. Owing to the exposed situations in which they live, they must fall an easy prey to rapacious birds. We obtained eighty-five specimens in one morning. The *Littorina littorea* occurred sparingly at various localities on the islands, but was found in great abundance at Scarboro, on the piles of a bridge, by Dr. Edw. Palmer. It has been supposed by several writers that this shell has been recently and accidentally introduced from Europe; but Dr. Dawson informs me that he collected it more than thirty years ago in the Gulf of St. Lawrence. It is abundant at Halifax, and we have other specimens from

Kennebunkport, Me., Hampton beach, N. H., and Provincetown, Mass. There is really no sufficient evidence that it was not an inhabitant of our shores before the advent of Europeans, but local in its habitats. It may have become more diffused in recent times, by commerce, or it may have been overlooked formerly by collectors.

One of the localities, most interesting zoölogically, that we visited, was a small shallow and sheltered cove, at the upper end of Quahog Bay, about thirty miles northeast from Portland. This place is well known to be inhabited by the round-clam or "Quahog" (*Venus mercenaria*), which is not found living elsewhere on the coast of Maine, so far as known to me. Indeed, this southern species is rare everywhere north of Cape Cod, on the New England coast, and is probably not to be found living north of Massachusetts Bay, except in the coves connected with Quahog Bay. It is also absent from the Bay of Fundy, but reappears in the southern and shallow parts of the Gulf of St. Lawrence. This anomalous distribution would be curious, even if it happened only in the case of this one species; but our investigation of this locality shows that there is quite a number of other southern species associated with the quahog, which have the same remarkable distribution, being absent along the rest of the northern coast of New England, and reappearing in the Gulf of St. Lawrence. There is, in fact, at this place a genuine colony of southern species, completely isolated from their co-species of the southern coast of New England, and surrounded on both sides by more northern forms. Several of these southern species, like the *Venus mercenaria*, *Crepidula convexa*, *Eurosalpinx cinerea*, *Eupagurus longicarpus*, *Epelys trilobus* Smith, *Meckelia ingens* Leidy, *Asterias arenicola*, etc., were not even met with among the islands and coves of Casco Bay; while others, such as *Ilyanassa obsoleta*, *Crepidula fornicata*, *C. plana*, *Limulus Polyphemus*, etc., occurred more or less frequently in the more sheltered and shallow waters of Casco Bay, though they are not found on the more exposed shores of Maine and New Hampshire, farther to the south and west, but have their true homes south of Cape Cod. Native oysters also occur, in a similar way, farther eastward than Quahog Bay, near Damariscotta, though it is not probable that they are indigenous elsewhere on the New England coast, north of Cape Cod,—as they certainly are not north of Massachusetts Bay,—yet they reappear in the Gulf of St. Lawrence, with the other southern forms.

In fact, the southern part of the Gulf of St. Lawrence, from Chaleur Bay to Prince Edward Island and Cape Breton Island, is a region of shallow water, occupied by another southern colony, but a much larger one than that of Quahog Bay, and contain-

ing, perhaps, a few southern species that do not occur in the latter locality; though owing to the fact that we could spend but a few hours at this place, our collection is doubtless quite incomplete. On the other hand, we have, with the exception of the shells, very imperfect lists of the southern species inhabiting the colony in the Gulf of St. Lawrence, so that a complete comparison cannot be made, at present, except with the shells; these agree very closely, according to the lists given by Dawson, Bell, and Whiteaves.

As the existence of these isolated southern colonies has an important bearing upon the question of former changes of climate on our coast, and as other facts, to be mentioned further on, are intimately connected with them, I give here a list of the species obtained by us, in the cove referred to, so far as they have been identified.

List of species collected at low-water in a small cove at the upper end of Quahog Bay.

Those with an asterisk prefixed are decidedly southern species, belonging properly to the region south of Cape Cod.

ARTICULATA.

Crustacea.

Cancer irroratus.	Gammarus ornatus.	Limnoria lignorum.
*Eupagurus longicarpus.	Amphithoë, sp.	*Argulus, sp.
Crangon vulgaris.	*Epelys trilobus *Smith*	*Limulus Polyphemus.
*Mysis stenolepis *Smith.*	Idotea irrorata.	Balanus balanoides.

Annelids.

Lepidonotus squamatus.	*Rhynchobolus dibranchiatus.	Fabricia Leidyi.
Nephthys ingens.		Spirorbis borealis.
Nereis virens.		

Turbellaria.

*Meckelia ingens.	Nemertes viridis.	*Nemertes socialis.

MOLLUSCA.

Gastropods.

*Urosalpinx cinerea.	*Crepidula convexa.	Littorina palliata.
Purpura lapillus.	*C. fornicata.	Lacuna vincta.
*Ilyanassa obsoleta.	*C. plana.	Rissoa aculeus.
Tritia trivittata.	Littorina rudis.	Acmæa testudinalis.
Natica heros.		

Lamellibranchs.

Saxicava arctica.	Macoma fragilis.	*Modiola plicatula.
Mya arenaria.	*Petricola pholadiformis.	Anomia aculeata.
*Venus mercenaria.	Mytilus edulis.	

Bryozoa.

Alcyonidium hispidum.	Alcyonidium hirsutum.

RADIATA.

Echinoderms.

* Asterias arenicola.

Hydroids.

Sertularia pumila. | Obelia geniculata. | Clava leptostyla.

Polyps.

Metridium marginatum.

Although the species in this list, that are not marked as southern, have a continuous range northward to the Gulf of St. Lawrence, and many of them to the Arctic Ocean, North Pacific, and northern Europe, they all extend as far south as Long Island Sound, and several of them even to North Carolina. Most of them are, therefore, northern species having a wide distribution, and their presence in this particular locality has no special significance.

In Quahog Bay itself we found the bottom composed of soft sticky mud, and in this we dredged, in 4 to 6 fathoms, a great number of large and fine specimens of *Yoldia limatula* and *Macoma sabulosa*, with a number of other common species.

That the Quahog Bay colony has formerly, and within the human period, been more extensive than at present, is shown: 1,—by the fact that the quahogs have evidently been, at one time, more numerous and more generally diffused than now, for their shells are abundant in the mud. in places where no living ones could be found; 2,—by the occurrence of oysters, in great quantities and of large size, in the ancient Indian shell-heaps of this region, and also near Damariscotta, while at present the oysters found there are few and small; 3,—by the occurrence of the shells of the quahog, of large size, in the Indian shell-heaps on many of the islands in Casco Bay (these heaps consisting mainly of the shells of the "long clam," *Mya arenaria*, with a few bones of fishes, birds, and mammals).

That at a more remote period, the marine climate of this region was still warmer,* and the southern species were more abundant than during the period when the Indian shell-heaps were formed, is shown by the occurrence of great beds of oyster shells a few feet beneath the mud in Portland Harbor, where they are associated with quahogs and several other southern species, among which are *Callista convexa*, *Turbonilla interrupta*, and *Pecten irradians*. The latter is not known to live, at present, north of Cape Ann, on the New England coast. It is absent, apparently, from the colony in the Gulf of St. Lawrence, as well as from that of Quahog Bay. It is very rare north of Cape Cod.†

* The evidence here given is probably applicable chiefly to the temperature of the warmer months, or more properly to the reproductive season of the mollusks referred to, for the climatic distribution of most marine animals seems to depend mainly on the temperature of the season at which reproduction takes place.

† Willis includes this species in his nominal list of Nova Scotia shells, but without mentioning the special locality. It may, perhaps, occur in some of the sheltered localities near Halifax, where another southern colony exists.

The *Callista convexa* is still found sparingly in shallow, sheltered localities in Casco Bay, and rarely at Eastport, Me., but it is more common in the colony of the Gulf of St. Lawrence, and very common south of Cape Cod. But the oysters (*Ostrea Virginiana*) and "scollops" (*Pecten irradians*) had apparently become extinct in the vicinity of Portland Harbor before the period of the Indian shell-heaps, for neither of these species occur in the heaps on the adjacent islands, while the quahogs lingered on until that time, but have subsequently died out everywhere in this region, except at Quahog Bay. The oysters have survived only in the locality near Damariscotta, though far less abundant there than during the Indian period.

The beds of dead shells of oysters, *Pectens*, etc., were found in making excavations in the harbor with mud-digging machines. These beds extend up to or above low-water mark, and are of great extent. Mr. C. B. Fuller, who has made a good collection of these shells for the Portland Natural History Society, informs me that the farmers have, in some instances, found it profitable to cart away these ancient shells for fertilizing purposes. The position of these beds indicate that no important change in the relative level of the land and water can have occurred in that region since they were formed. These beds are, of course, easily distinguished from the much more ancient Post-Pliocene deposits that occur abundantly in the same region, but extend back several miles from the coast, and occur at all levels, from low-water mark to about 200 feet above high-water mark. The latter are characterized, in that region, by a more arctic assemblage of shells than that now inhabiting the adjacent waters, though most of the species still survive, in deep water, off the coast of Maine

The facts above presented indicate: 1,—that in the Post-Pliocene and Champlain periods the coast was at a lower level, and the marine climate of Casco Bay was colder than at present, probably about like that of the present Newfoundland or Labrador coast; 2,—that at a subsequent period, when the coast had attained nearly or quite its present level, the marine temperature was considerably higher than at present; 3,—that the temperature of these waters has gradually declined, but was still somewhat higher at the period when the Indian shell-heaps were formed than at present.

That the existence and character of the southern colony in the Gulf of Saint Lawrence points to the same conclusion is sufficiently obvious. The survival of the southern species in that region is undoubtedly due to the great expanse of shallow water in that part of the gulf, which becomes well warmed up by the heat of the sun, in summer; and to the absence of tides sufficiently powerful to thoroughly mix up the very cold waters

of the northern and deeper portions of the gulf with the warm waters of the southern part. Tides like those of the Bay of Fundy and coast of Maine would undoubtedly at once diminish this contrast in the temperature of the different parts of the gulf, and greatly lessen the temperature of the southern part, by reason of the far greater volume of the cold water.

The *origin* of the southern species in the gulf is a totally different matter. I can explain their presence there in no other way than to suppose that they are survivors from a time when the marine climate of the whole coast, from Cape Cod to Nova Scotia and the Bay of Fundy, was warmer than at present, and these species had a continuous range from southern New England to the Gulf of Saint Lawrence. At that time there may have been a direct shallow passage from the Bay of Fundy across to the Gulf of Saint Lawrence, for the land is there narrow and low; but of this we have no direct evidence. A *deep* channel there would act like the Straits of Belle Isle, and admit the cold arctic current to the coast of Maine; this may have been the case in Post-Pliocene times.

The causes of such changes in the temperature of the water may have been entirely local, and due to changes in the relative level of the land and water, in adjacent regions. Thus a rise of the land in the region of Saint George's Bank, to the extent of 250 feet, would produce an island quite as large as the State of Massachusetts, and would thus very materially alter the climatic conditions of the "Gulf of Maine," between it and the New England coast. And it would add a great body of land, now represented by Le Have Bank, etc., to the southern part of Nova Scotia, and thus greatly narrow the channel between those banks and St. George's, as well as make it more shallow; this would doubtless greatly modify the tides, and greatly diminish their force and height on the coasts of northern New England, and in the Bay of Fundy, for the "Gulf of Maine" would then have much resemblance to the Gulf of Saint Lawrence in form, and in the character and position of its main channel, and, therefore, its tides would also be similar; the small tides would allow greater differences between the temperatures of the shallow waters and deep waters, and would thus favor the southern species inhabiting shallow water. A rise of the land, of about the same amount, in the region of Newfoundland, would lay bare a great part of the Grand Banks, close up the Straits of Belle Isle, and more than double the size of Newfoundland, which would doubtless produce great climatic changes on the New England coast, as Professor Dana has suggested.

[To be continued.]

ERRATUM.—p. 134, for *Eurosalphinx* read *Urosalphinx*.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the Amount of Carbonic gas in the Atmosphere.*—Truchot has recently made a series of determinations of the amount of carbonic gas in the atmosphere. His method of analysis consisted in passing a known volume of air through a graduated solution of barium hydrate, allowing the barium carbonate to deposit, and re-titring the solution. He finds: 1st, that at Clermont-Ferrand, where the experiments were made, the proportion of carbonic gas is a little greater during the night than in the daytime; a fact confirmatory of the observations of Saussure and Boussingault. 2d, that the proportion is not sensibly greater in the city than in the open country. 3d, that in the vicinity of green-leaved plants, the quantity of carbonic gas varies notably, according as the green parts are exposed to full sunlight, to diffused light or are in the shade; the amounts being 3·54, 4·15 and 6·49 parts in 10,000 of air. 4th, that the general mean is 0·814 milligram of carbonic gas to the liter of air, or 4·09 parts in 10,000; a number very near that usually received. 5th, that the proportion of carbonic gas diminishes with the altitude, thus:

Station.	Altitude.	Wt. CO_2 to the liter.	Vols. of CO_2 in 10,000 of air.
Clermont-Ferrand,	395^m	0·623^{mg}	3·13
Puy-de-Dôme,	1446	0·405	2·03
Pic-de-Sancy,	1881	0·342	1·72

—*C. R.*, lxxvii, 675. *Bull. Soc. Ch.*, II, xx, 494, Dec., 1873. G. F. B.

2. *On Hydrogen Arsenide.*—Janowsky has made some experiments upon the decomposition of hydrogen arsenide. He prepared the gas from sodium arsenide by the action of water, or preferably of very dilute acids; the sodium arsenide itself being prepared by heating sodium in hydrogen arsenide obtained from arseniferous zinc. When passed through phosphorous chloride in the cold, a red-brown powder of arsenous phosphide is thrown down, formed as follows:

$$PCl_3 + AsH_3 = (HCl)_3 + PAs.$$

This substance, separated from the liquid and dried in a current of carbonic gas at 70° to 80° C., is a dark red-brown lusterless powder, containing 70·53 per cent of arsenic and 29·11 per cent of phosphorus. Water decomposes it, yielding a substance having the formula $As_3P_2O_2$. It is insoluble in alcohol, ether and chloroform, and in sulphuric and hydrochloric acids. CS_2 dissolves it in small quantity. By nitric acid, it is oxidized to arsenic and phosphoric acids. Alkali-hydrates decompose it, producing hydrogen phosphide and arsenide, arsenite and phosphite and metallic arsenic. It burns in the air, yielding phosphoric and arsenic acids. In close vessels, it decomposes on heating, into phosphorus and arsenic, which sublime. The author also observes

that hydrogen arsenide is decomposed both by concentrated sulphuric and hydrochloric acids, depositing, not a solid hydrogen arsenide, but arsenic itself, and evolving in the case of the former, sulphurous acid. In contact with arsenous chloride, hydrogen arsenide is decomposed, yielding metallic arsenic and hydrochloric acid, thus:

$$AsCl_3 + AsH_3 = (HCl)_3 + AsAs.$$

Hence the author's inference, that the attraction of the two arsenic atoms for each other is greater than their attraction for the chlorine and hydrogen atoms respectively. Finally, on treating sodium arsenide with water, gaseous hydrogen arsenide is abundantly evolved, and a brown velvet-like residue is left, which gave on analysis the formula AsH.—*Ber. Berl. Chem. Ges.*, vi, 216, 1873. G. F. B.

3. *On the Sensitiveness of silver bromide to the so-called Chemically Inactive rays.*—It is well known that with ordinary silver plates the chemically active portion of light is the violet or ultra-violet. Tested in the spectrum, this portion extends only as far as the line E in the green. VOGEL has now discovered the remarkable fact that by suitable treatment, silver plates may be rendered sensitive to any of the rays of the spectrum at pleasure, even to the red. His attention was called to this subject by observing that some dry plates, prepared with silver bromide, received from Wortley in England, were more sensitive to the green rays, near the line E, than to the bright blue, near the line F. This led to an investigation into the sensitiveness of silver bromide to the various colors of the spectrum. This spectrum was produced by a direct-vision prism, receiving its light from a slit $0{\cdot}25^{mm}$ wide, illuminated with sunlight from a Foucault's heliostat. The image was produced by a Steinheil's camera lens, the portion of the spectrum from D to G being 35^{mm} in length. The experiments were all made from 11 to 2 o'clock in the day and during a cloudless sky. The time of exposure was generally ten minutes, and the plates were developed with solution of ferrous sulphate. It was at once observed that the bromide was sensitive to rays beyond the line F, rather than short of it, as had been supposed. Moreover, while wet plates, with an acid developer, were found to be sensitive to rays extending nearly to the yellow (to between D and E), dry plates were affected by rays two millimeters beyond D; i. e., rays in the orange. In the former case, the most intense action took place between G and F; diminishing rapidly beyond F toward E. In the latter, though the action in the blue was much weaker, its decrease was much less rapid. The author concludes from this that dry silver bromide is the more delicate for the less refrangible, wet silver bromide the more delicate for the more refrangible rays. In all the dry plates prepared by him, however, no such increase of sensitiveness from the blue toward the green was shown as was exhibited by the English dry plates above mentioned. In casting about for a reason for this, the common explanation of the use of a silver solution as a sensitizer,

i. e., that since the action takes place principally in the blue, this solution acts by absorbing the blue rays—occurred to him, and he concluded that the English plates must contain some substance which absorbed green light more strongly than blue. Upon examination, the Wortley plates were found to contain uranium nitrate, gum, gallic acid, and a yellow coloring matter as a protective. Upon removing this yellow coating the plates were found to be no longer sensitive to the green rays. Vogel now directed his experiments to obtain a material with which to impregnate the silver bromide, which, while uniting, like the silver solution, with the iodine or bromine set free in the action, should at the same time absorb strongly the yellow rays and thereby increase the sensitiveness of the silver bromide for yellow. Such a substance he found in corallin, the solution of which showed a strong band at D in its absorption spectrum, while at the same time, it transmitted considerable blue light. Dissolving the corallin in alcohol, he added it to his collodion until it was colored strongly red. Plates prepared with this collodion were found to be sensitive to the indigo rays; but the sensitiveness decreased toward the blue, was weak at F, and increased again in the green, becoming *in the yellow almost as great as in the indigo!* In corallin therefore we have a substance by means of which a color, yellow, hitherto considered chemically inactive, may be made as effective photographically as the indigo itself. Extending his investigations, Vogel observed that the green aniline colors, which absorb the red rays between D and C, render sensitive a silver bromide-collodion, even to the red rays. The sensitiveness decreases from the indigo to the yellow, then increases again, attaining its maximum at the precise point where the absorption band is situated. The author believes therefore that bromide of silver may be made sensitive to any color at will and suggests that it may be as possible to photograph the ultra-red as the ultra-violet spectrum. At all events, he photographed a blue band on a yellow ground, obtaining in the picture a dark band on a light ground. Sensitiveness to light in a plate is dependent, consequently, not only upon the absorptive power of the silver salt itself, but also upon that of the substances with which it may be mixed.—*Ber. Berl. Chem. Ges.*, vi, 1302, Nov., 1873. G. F. B.

4. *On the Existence of Chromium dioxide.*—HINTZ has investigated, in the laboratory of Dr. Lothar Meyer, the methods of preparation and properties of chromium dioxide. He used: (1) Vanquelin and Brandenburg's method, decomposing chromic nitrate by heat. The result contained too little oxygen. (2) Kopp's method, by the action of chromic acid on chromic hydrate. (3) Döbereiner's, by heating chromic acid; the product was not uniform. (4) By heating chromic hydrate with free access of air. Result unsatisfactory. (5) Schweitzer's method, by passing nitrogen dioxide gas into a moderately dilute solution of potassium dichromate; product was a brown hydrate. (6) Schiff's method, by the action of chloride of lime on chromic hydrate; no result.

The product by Schweitzer's method—the fifth above given—when dried at 250° till the weight is constant, approaches very near to the composition of chromium dioxide. It is a fine deep black very hygroscopic powder, forming a dark red-brown hydrate. Chlorine has scarcely any action upon it even at 250°. Hydrogen chloride gas acts only very slightly, evolving water and chlorine and forming the violet chloride. Black chromium dioxide is therefore an extraordinarily indifferent body, essentially different in this respect from molybdic oxide. This suggests that instead of being a simple oxide CrO_2, it may belong to the so-called saline oxides, Cr_2O_3,CrO_3.—*Ann. Chem. Pharm.*, clxix, 367, Oct., 1873. G. F. B.

5. M. STEFAN has conducted a series of *experiments on the evaporation of volatile liquids, especially ether.* Such experiments have hitherto led to no results expressible in the form of laws. The conditions under which they were made were not simple enough; yet they were sufficiently varied. The science of evaporation, especially of the diffusion of vapors, remained an unoccupied field.

In the following experiments, to avoid the great lowering of the temperature at the surface, narrow tubes were chosen for evaporating vessels, instead of the wide vessels hitherto used.

(1.) The velocity of the evaporation of a liquid from a tube is inversely proportional to the distance of the level of the liquid from the open end of the tube. This law holds with rigorous exactness when the distance of the level a little exceeds 10^{mm}.

(2.) The velocity of the evaporation is independent of the diameter of the tube. This result was obtained from experiments with tubes the diameter of which varied from $0{\cdot}3^{mm}$ to 8^{mm}.

(3.) The velocity of the evaporation increases with the temperature, so far as with this the vapor-pressure of the liquid rises. If p be the maximum of elasticity of the vapor corresponding to the temperature of the observation, P the atmospheric pressure under which the liquid evaporates, the velocity of the evaporation is proportional to the logarithm of a fraction of which P is the numerator and P–p the denominator. If the pressure of the vapor becomes equal to that of the air, this logarithm becomes infinitely great, and signifies that under this condition the liquid boils.

Experiments were also made on evaporation in closed tubes.

If the open end of a tube, the other end of which is closed, be dipped in ether, bubbles form and issue continually from the tube, and at first the times in which successively equal numbers of bubbles form, are proportional to the odd numbers.

If the immersed tube contains hydrogen instead of air, the same number of bubbles form in one-fourth of the time. Evaporation proceeds in hydrogen, therefore, four times as rapidly as in air.

The same result was also furnished by an experiment in which a liquid can be evaporated in an open tube in various gases. It consists of a T-shaped glass tube, through the horizontal cross-

piece of which a continual current of the gas is conducted, while the liquid to be evaporated enters the vertical arm.

If a tube provided with a cock be dipped with the cock open in ether, the level of the liquid within the tube will sink below that outside; and at first the depths to which the interior level sinks below the exterior in definite times are as the square roots of those times.—*Philos. Mag.*, xlvi, 483. E. C. P.

6. Prof. VILLARI has *measured the time required by flint glass to change its magnetic condition, or to rotate the plane of polarization.* A beam of polarized light was passed through the poles of a powerful electro-magnet and a glass cylinder interposed, which acted like a cylindrical lens. This cylinder could then be turned end over end with any desired velocity. When not magnetized, it of course produced no effect on the plane of polarization whether in motion or not. But when caused to revolve rapidly, the angle through which it turned the plane of polarization was considerably diminished, since in each revolution it remained in the axial direction too short a time to acquire its full magnetic polarity. To impart sufficient diamagnetic intensity to be perceptible by the change of plane, at least ·0012″ was required; while to produce the complete effect, 0024″ was necessary.—*Pogg. Annalen*, No. 7, 1873. E. C. P.

7. M. E. DUCHEMER addresses a note to the French Academy, in which he claims that *a circular compass needle possesses the following advantages* over the usual form:

1st. A magnetic power, for a given diameter, double that of a needle whose length is equal to this diameter.

2d. The existence of two neutral points instead of one, which has the effect of maintaining the position of the two poles constant; the magnetism seems to be so energetically preserved, that even the strongest sparks of a Holtz machine do not cause any displacement of the poles of the magnet.

3d. A more satisfactory means of suspending the magnet when it is well mounted and balanced by a plate of agate; it seems then to move as if placed in a liquid.

4th. An increase in sensibility of the magnet proportional to its diameter.

5th. The possibility of neutralizing the magnetism of the vessel by means of a second magnetic circle, changing the position by an amount calculated beforehand, and thus permitting the compensation of the compass before the sailing of the vessel. This idea was suggested by Capt. D. Venie.—*Comptes Rendus*, lxxvii, 890. E. C. P.

8. Dr. J. B. SANDERSON presented a note to the Royal Society *on the electrical phenomena which accompany irritation of the leaf of Dionæa muscipula.*

When the opposite ends of the living leaf of this plant are placed as non-polarizable electrodes and connected with the terminals of a Thomson's galvanometer, a deflection is produced which indicates a current from the proximal to the distal end of

the leaf. This current he calls the *normal leaf-current.* If, instead, the leaf stalk is placed on the electrodes (the leaf remaining united to it) in such a way that the extreme end of the stalk rests on one electrode, and a part of the stalk at a certain distance from the leaf on the other, a current, called a *stalk-current*, is indicated, opposed to that in the leaf. To show these currents, it is not necessary to expose any cut surface to the electrodes.

In a leaf with the petiole attached, the strength of the current increases as the length of the petiole diminishes. Thus, a leaf with a petiole an inch long gave a deflection of 40 divisions, and by successively reducing its length one-half, this deflection was increased to 50, 65, 90 and 120. Partially severing the leaf gave the same result as if it was completely cut off.

If the leaf is placed on the electrodes as before, on introducing the petiole into the circuit of a small Daniell, the deflection is increased when the current passes down the petiole, that is, from the leaf. On reversing the current the deflection is diminished.

If, the leaf being so placed that the normal leaf-current is indicated by a deflection to the left, a fly is allowed to creep into it, it is observed that the moment the fly reaches the interior (so as to touch the sensitive hairs on the upper surface of the lamina) the needle swings to the right, the leaf at the same time closing on the fly.

The fly having been caught does not remain quiet, and each time it moves, the needle again swings to the right, always coming to rest in a position somewhat farther to the left than before, and then slowly resuming its previous position.

The same effects are observed in touching the sensitive parts of the still open leaf with a camel's-hair pencil, or pinching the closed leaf with a pair of forceps.

Placing the leaf-stalk and leaf on the electrodes as before, the stalk current is seen to be increased, whenever the leaf is irritated as above.

If the open leaf having been placed on the electrodes, one of the concave surfaces is pierced with a pair of platinum needles connected with the secondary coil of a Dubois Raymond induction apparatus, it is observed that when the circuit is closed the needle swings to the right, as when irritated mechanically. No difference is observed when the induced current is reversed. The observation may be repeated any number of times, but no effect is produced unless an interval of from ten to twenty seconds has elapsed since the preceding irritation.

If the part of the concave surface of the leaf nearest the petiole is excited, the swing to the right is always preceded by a momentary jerk of the needle to the left. This effect cannot be produced by irritating any other part of the concave surface of the leaf.

An interval of from a quarter to a third of a second always intervenes between the act of irritation and the negative variation.—*Nature*, ix, 75. E. C. P.

II. Geology and Natural History.

1. *Volcanic Energy: an attempt to develop its true Origin and Cosmical Relations;* by Robert Mallet, A.M. F.R.S., etc.—This important paper is now published in full in the Journal of the Royal Society, having been read in abstract June 20, 1872.

The author accepts in general Sir W. Thomson's view, that plutonic action or "Vulcanicity" results from the dissipation of energy in the shape of terrestrial heat. Setting aside as untenable, upon the basis of observed facts, all other hypotheses, he develops the idea first distinctly expressed by Constant Prevost, that elevation, folding and crushing of strata is the result of tangential pressure, originating in the contraction of the earth's crust by secular refrigeration; considering the latter, as well as the general increase of temperature, with depth, as facts sufficiently established.

Assuming that in consequence of the viscosity of the cooling materials, the temperature would, after a certain epoch, always have been highest near the center of the mass; and that a crust began to form at the poles, advancing in hemispherical sheets toward the equator, he argues that tangential pressures caused in the thin, hot crust by contraction, would *first* be met by the formation of wrinkles; the crust, even if dislocated, remaining at the surface by virtue of the thick viscous *couche* beneath, and not sinking into the latter, still less to the hot central portion. After the crust had thickened still further, the rapid contraction may reasonably be conjectured to have resulted in the rough outlining of our present seas and continents, by deformation. The sudden contrary flexures at the junctions of the continents and sea-basins initiated lines of weakness in the early crust. During a third period, the crust becoming still thicker and more indurated, and the viscous bed beneath greatly thickened, so as to cut off convection; the former became capable of transmitting tangential stresses within itself, and began to corrugate and double upon itself, elevating mountain chains along the lines of weakness, and extruding rocks, now forming dykes and intrusions. Lastly, during a fourth period, of a greatly thickened and stiffened crust, and slow rate of cooling, began that balance and play of forces, the effects of which are now recognized as volcanic.

Vulcanicity may, according to the author's view, be thus defined: "The heat from which terrestrial volcanic energy is at present derived is produced locally within the solid shell of our globe, by transformation of the mechanical work of pressure, or of crushing of portions of that shell; which compressions and crushings are produced by the more rapid contraction, by cooling, of the hotter material of the nucleus beneath that shell, and the consequent more or less free descent of the shell by gravitation; the vertical work of which is resolved into tangential pressures, and motion, within the thickness of that shell."

As regards the modus operandi of this agency, Mallet considers mainly three points, viz: 1. Evolution of heat by compression of rocks within the limits of elasticity; 2. Friction, by sliding of beds, or planes of fracture upon each other; 3. Rock crushing. These, acting severally or jointly, and more or less localized both vertically and horizontally, are adequate to explain, not only the irregularities observed in the increase of temperature, but when acting in the presence of water, constitute also an adequate cause of vulcanicity. "To prove this it is necessary to show, 1st. That the gravitation of the unsupported shell is adequate to crush into powder all the materials of which it consists, no matter how thick the shell may be, unless equal to the radius; 2d. What is the total amount of contraction of materials analogous to the rocks of the solid shell, between the temperature of fusion (or one above it) and that of our atmosphere now; 3d. What is the mean work per unit of weight and volume necessarily expended in crushing to powder the rocks of which the solid shell consists, and what is the amount of heat due to the transformation of such work."

Concerning the first point, Mallet deduces from known data and assumed conditions largely within the limits of probable maxima, that in an unsupported shell, the crushing force by horizontal thrust would exceed at least 428 times that required for crushing (a free cube of) the hardest known rocks; and that no practically possible conditions will suffice to prevent crushing under such pressures. He then proceeds to investigate experimentally the question as to the amount of heat produced by rock-crushing, and whether that amount be sufficient to account for existing volcanic phenomena. Having tested by preliminary experiments the correctness of Hirn's statement, that in crushing very inelastic bodies, the heat evolved is almost precisely the equivalent of the work expended in deformation, he crushes a series of cubes ($1\frac{1}{2}$ inch square) of different rocks, from soft oölite through limestones and sandstones to granite and porphyry, in the testing machine (designed by Ramsbottom) of the Reeve Locomotive Works; every precaution being taken to insure accuracy. The pressures at which disintegration commenced, and those at which the final crush-down to powder occurred, were noted, as well as the distance through which the crushing plunger had descended at either point. The elevation of temperature by crushing was in all cases very perceptible, and in those of the harder rocks very considerable. It was not directly determined, but calculated by the aid of Joule's equivalent number, and the (known or re-determined) specific heats and gravities of the rocks.

From the elaborate table in which these results are given and discussed, it appears that the mean work expended in crushing one cubic foot of the rocks experimented upon, varied from 255,951·39 footpounds for oölite, to 5,653,722 in gray Guernsey granite, the corresponding increase of temperature being respectively 8·004° and 217·24° F. Upon the basis of his experiments, and of general considerations, he obtains for the "mean rock" of the first 100 miles of crust, the following data:

British heat-units per cub. foot of rock crushed,..... = 6472
Temperature Fahr. to which it is raised,..... =183·74
Cub. foot of rock at 300° F., fusible at 3,000° by crushing 1 cub. foot of mean rock,..... = 0·108

the liquefaction of one cubic foot of ice at 32° being equivalent to the crushing work of 1·277 cubic foot of mean rock.

Passing to the question of the total contraction of fused mineral masses, Mallet shows the unreliability of the experiments heretofore made on the subject by Bischof, Forbes and others. His own experiments were made by casting iron-furnace slag, very similar in composition to basalts, in very large and thick hollow iron cones, open at both ends, but placed upon iron bed plates. The cones were seen full of liquid slag of about 3680° F., and its volume accurately measured at the moment when a self-supporting crust had formed all around, at a temperature of about 3,000°. The slag cones were again measured, after cooling, at 53° F.; and the results deduced, with many precautions and corrections, are these:

Mean coëfficient of contraction from fluidity to solidification,
3680° to 3000° F. = 0·982·0
3680° to 53° 0·932·76

which is about 6 per cent, against 20–25, as determined by Bischof.

The earth's diameter being at present 7,916 miles, it must have been when liquid =8,105 miles, having shrunk by 189 miles at least. This represents more than the work of a shell of 94½ miles thick, falling through 47 miles.

As for the present rate of cooling, whichever of the coëfficients usually given we adopt, the annual loss cannot be less than 575 to 777 cubic miles of ice melted to water at 32°. If the total amount annually lost were produced by rock-crushing, it would take 987 cubic miles of crushed rock. But doubtless by far the greater part reaches the surface from a cooling nucleus, and but a small portion is manifested as vulcanicity. Upon an estimate of the entire mass of volcanic cones known, Mallet comes to the conclusion that 7,200 cubic miles of crushed rock would have sufficed (thermally) to produce them; which amount represents the loss of heat for eight years only, whereas the actual period of time elapsed during their production is immense.

Having proved that the crushing of the earth's solid crust affords a supply of energy sufficient to account for terrestrial vulcanicity, and that the necessary amount of crushing falls within the limits that may be admitted as due to terrestrial contraction by secular refrigeration, Mallet proceeds to discuss the potent reasons leading to the assumption of a thick crust, and the inadmissibility of either supposing water to reach the liquid nucleus from the surface, or that the fused materials of that nucleus could be forced up through such enormous distances. The yielding of the crust to contraction will naturally be, not continuous, but *per*

saltum, and more or less localized along lines of especial weakness, at points constantly displaced by these very acts. The effects are therefore irregularly intermittent, and non-periodic; as are volcanic eruptions and earthquakes. The linear arrangement of volcanoes, and their general parallelism to great mountain chains, thus also finds its natural explanation. The volcano is a safety valve for the earthquake, in so far as its activity prevents the accumulation of virtual energy, to the extent that on sudden yielding, widely destructive cataclysms would ensue.

A parallel train of reasoning applied to the moon at once explains its apparent present condition. If vulcanicity be dependent upon secular cooling, then the smaller the planet, the more intense should be volcanic energy, and the briefer its duration.

If, then, the cause assigned is adequate, and all parts of the theory fit together with the facts, the author submits that the theory may be regarded as a true interpretation of Nature.

E. W. H.

2. *Geology of the Cobequid Mountains, Nova Scotia;* by D. Honeyman. (From the Proceedings of the Nova Scotia Institute of Natural Science.)—The railway opens up in a beautiful manner the geological structure of the Cobequid mountains. The most instructive part of the section is that which traverses the mountains on the Cumberland side of the county line. The central or syenitic formation extends along the line of railway a distance of 24,000 feet; of this 12,900 feet is in the county of Cumberland. On either side of this is the Lower Silurian. On the Colchester side this formation has its largest development, having a width of 10,400 feet. On the Cumberland side the width is 8,800 feet. This is a fact of possible economic importance. It is a great metalliferous, as well as marble-containing series. This is the first time that this formation has been distinctly recognized in these mountains. On the Cumberland side this formation has, in its lower part, diorites and diorite porphyries, and a considerable number of other porphyries, jasper rocks, conglomerate, jaspideous and amygdaloidal. The last correspond exactly with the Quebec conglomerates of Canada, which are copper-producing. Above the conglomerates is a considerable thickness of diorites, shales and slates, which are regularly interstratified. The shales contain abundance of fossils of older forms than any yet found in Nova Scotia. These are in the finest state of preservation. *Graptolites* of the most delicate and beautiful forms are in a state of preservation unexampled in such rocks. *Trilobites* and *Lingulæ* of forms strange to Nova Scotian geology are also found. These are of *Hudson River* age, the upper part of the Lower Silurian.

This important discovery, made by the author on the 17th of September, has solved a very important problem regarding the age and succession of the older metamorphic rocks of Nova Scotia and Cape Breton, and possibly also of New Brunswick. The vertical thickness of the fossiliferous and interbedded dior-

ites is 770 feet. Succeeding the Lower Silurian on the Colchester side is a band of Middle and Upper Silurian, about 2,000 feet wide. This is the band which contains the Londonderry iron deposits. Here they are not apparent. On the Cumberland side the corresponding Middle Silurian band has a width of 3,000 feet. One fossil, a *Lingula*, was found in the lower part.

Succeeding the Middle Silurian, on the Colchester side, is a great width of the Carboniferous formation. This shows neither limestone, gypsum nor coal.

On the Cumberland side is the Carboniferous formation, which contains its coal fields. The part of this formation which immediately lies upon the metamorphic formations of the Cobequids consists of conglomerates and sandstones. One remarkable feature of these two was that they contained embedded blocks of syenite of 200 pounds and upward at a distance of 2¼ miles from the original rock of the mountain. Fossil plants embedded in the sandstone with these rocks are found closely adhering to the latter.

In Mr. Amos Purdy's Freestone quarry, at Wentworth, in connection with these conglomerates and sandstones, sandstones were found having abundance of rain prints, rill marks, fossil plants and abundance of footprints of small and large reptiles. One reptile had trodden on a fern leaf which lay in the rain-pitted mud, and another had dragged its tail in its slow march.

Succeeding the Carboniferous on the Colchester side is the Triassic, or New Red Sandstone. This extends to Truro on the line of railway. On the Cumberland side it is absent.

3. *On a shale* (*Brandschiefer*) *in the Lower Permian near Pillnitz in Saxony;* by EUGENE GEINITZ.—This shale, according to Mr. Geinitz, has afforded remains of the fish, *Acanthodes gracilis* Beyrich; wings of *Blattina Weissigensis* E. Geinitz, and another near *B. acanthophila* Germar; *Gyromices Ammonis* Göpp. (the little Serpula of the Coal-measures, made a fungus by Göppert; besides species of *Calamites*, *Asterophyllites*, *Annularia*, *Schizopteris*, *Sphenopteris*, *Hymenophyllites*, *Odontopteris*. *Callipteris*, *Neuropteris*, *Dictyopteris*, *Cyatheites*, *Alethopteris*, *Walchia*. *Cardiocarpus*, *Sigillariostrobus*, and the Cycads *Pterophyllum Cottæanum* Gutbier, *Pt. blechnoides* Sandb.; also *Cordaites Ottonis* Gein., *C. principalis* Germar, *C. Roesslerianus* Gein., *Pinites Naumanni* Gutb., *Schützia anomala* Gein. A plate representing the wings of *Blattinæ*, the fruit *Sigillariostrobus*, *Sphenopteris Naumanni*, and two species of *Pterophyllum*, accompanies the paper. The association of Triassic-like Cycads with Carboniferous plants—a fact pointed out before by Sandberger, and also by Prof. Geinitz for a Siberian locality—is a fact of great interest.

4. *Asmanite, a new species of Silica from a Meteorite;* by MASKELYNE.—Maskelyne found this mineral in the meteorite of Breitenbach, in which it occurs in colorless grains, 1 to 3 millimeters in diameter, along with nickeliferous iron, bronzite, chromite and troilite. It has the form of a right rhombic prism (I)

of 120° 20′, with the planes i-$\breve{\imath}$, 1-$\breve{\imath}$, $\frac{1}{2}$-$\breve{\imath}$, $\frac{1}{3}$-$\breve{\imath}$; and also rounded octahedral planes. The inclination of 1-$\breve{\imath}$ on the base is 117° 46′. Cleavage is distinct parallel to the base, and imperfect in the direction of the vertical prism I. Maskelyne also observed that the crystals are optically biaxial. Hardness between that of apatite and feldspar, or 5·5. Specific gravity 2·245, that of tridymite (another form of silica) being 2·3, and of quartz 2·6. An analysis afforded Maskelyne — SiO^2 97·430, Fe^2O^3 1·124, CaO 0·578, MgO 1·509 = 100·641. It is about as insoluble in a solution of carbonate of soda as quartz.

Vom Rath has examined the mineral and confirms the results of Maskelyne. He obtained for the specified gravity 2·247; and for the composition SiO^2 96·3, FeO 1·6, MgO 1·1=99·0. The presence of iron and magnesia is attributed to the presence of a little bronzite. The grains of asmanite may be separated from the rest by treatment with dilute chlorhydric acid. It is suggested by Maskelyne that quartz found by Partsch in the meteorite of Steinbach (which closely resembles that of Breitenbach) may have been asmanite.

5. *Mineralogische Beobachtungen V;* von Dr. Albrecht Schrauf. 88 pp. 8vo. (From the 67th volume of the Sitzb. of the k. k. Akad. der Wissensch. 1873. Wien.)—This memoir by the eminent crystallographer of Vienna, is an elaborate treatise on the mineral species of the Brochantite group. It gives a full exposition of the crystallization of the species, and of their chemical and physical relations.

6. *Geognostisch-mineralogische Fragmente aus Italien;* von Prof. G. vom Rath, of Bonn. Part IV, with two plates. (From the Zeitschr. of the Deutschen Geol. Gesellschaft, 1873.)—This 4th part of vom Rath's learned memoir consists of geographical, geological and mineralogical observations on the vicinity of Massa Maritima; on Calabria; and on Vesuvius. Under the last head, vom Rath has many important observations on the minerals formed at the eruption of 1872. He shows that the composition of *Microsommite* of Scacchi is related to that of the sodalite group, obtaining in his analysis,

$\dot{S}i$ 33·0, $\dot{A}l$ 29·0, $\dot{C}a$ 11·2, $\dot{K}$ 11·5, $\dot{N}a$ 8·7, $\dot{C}l$ 9·1, $\dot{S}$ 1·7=104·2;

and makes the important observation that nephelite, sodalite and microsommite, which are alike in occurring in the pores of lavas, have resulted alike from the action of sea water (rich in chloride of sodium) on the silicate of the lava. Microsommite occurs in hexagonal prisms, with pyramidal planes on the basal edges, and has 43° 40′ as the basal angle of the pyramid. Vom Rath concludes also that leucite was one of the results of sublimation at the eruption of 1872, as well as augite, hornblende, cavolinite, biotite, hematite and magnetite.

Vom Rath's paper on the crystallization of leucite, pointing out that it is tetragonal, is contained in Poggendorff's Annalen Erganzungsband, vol. vi; and the same paper treats of the crystalline forms of the Vesuvian augite and hornblende derived from subli-

mation, the forms of the crystals of sulphur; Arcanite of Roccalmuto; also of Jordanite from Binnenthal, mica of Vesuvius; epidote of Vesuvius; microsommite; and chalcomorphite, a new species from the lava of Niedermendig of the hexagonal system.

7. *Note on Anomphalus Meeki.*—Prof. F. B. Meek has called my attention to the figures of *Anomphalus rotulus*, the type of the genus, on plate XXIX of the recently-issued fifth volume of the Geology of Illinois. From these, it is evident that my species, *A. Meeki* (this Journal, August, 1872, p. 88), is not congeneric with *A. rotulus*. As I have been unable to learn of any genus to which it can properly be referred, I am obliged to consider it as the type of a new genus, for which I propose the name *Dawsonella*, in honor of the scientist who has done most to bring to our knowledge the land-snails of the Carboniferous. The most prominent characteristic of the type is the thin plate attached to the columella, and covering half or more than half of the aperture of the shell. In form, this reminds one of the similar plate in *Navicella*, with which genus, however, the shell has no apparent affinities. I see no reason to change my reference of this type to the *Helicidæ;* though the true *Anomphalus* probably belongs to the *Rotellidæ*, as stated by its authors.

F. H. Bradley.

New Haven, Ct., Jan. 20th, 1874.

8. *Glacial Period in New Zealand.*—Dr. Hector has shown that the Glacial period was a marked one in New Zealand geological history, and holds that the era was one of "prolonged though perhaps not excessive elevation"; and that "in consequence, especially in the South Island, there is a marked absence of marine drifts and tills."—*Nature*, Jan. 1.

9. *Fossils of New Zealand.*—Catalogues of fossils from the Tertiary formations, and also an illustrated work on the fossil plants from the different coal-bearing formations, are nearly ready for publication. Seven species of *Plesiosaurus* and related genera have been obtained at the Amuri Bluff (Marlborough) and at the Waipara.—*Ibid.*

10. *Addendum to Article XLVII*, vol. vi; by the author, T. B. Comstock.—Concerning the age of the Bridger and Green River groups, referred to the Miocene by Hayden, there is still much dispute, one of the best authorities expressing confidently the opinion that they must be considered Eocene.* In this paper I have followed Hayden's classification provisionally only. For the present I prefer to express no decided opinion.

I am indebted to Dr. J. S. Newberry for a review of my Silurian fossils from the Wind River Mts., resulting in the discovery that this formation is there made up of rocks of the Quebec group of the Calciferous epoch overlaid by a considerable thickness of the Niagara limestone.

The Niagara limestone and the Oriskany sandstone are new formations to this region.

Cleveland, O., January 1, 1874.

* Prof. O. C. Marsh writes me that he has obtained abundant evidence of the Eocene age of these beds.

11. *Stibioferrite from Santa Clara Co., California;* by E. GOLDSMITH.—This antimonial mineral occurs on stibnite, constituting layers from a thin coating to a quarter of an inch in thickness, and sometimes crystallized in cavities. The crystals were orthorhombic, and are rhombic prisms of 110° 8′, with the vertical edges truncated. It is opaque when amorphous, but subtranslucent when crystallized; the luster resinous, of a faint yellow color, with the streak dull yellow to straw-yellow. Hardness =4. G.= 3·518. B.B., in the closed tube yields water and a white sublimate; on charcoal, metallic globules and a white incrustation, with fumes on stopping the heat; insoluble in nitric acid; soluble in hydrochloric. An analysis afforded, after deducting 8·84 of quartz, Sb^2O^3 47·69, Fe^2O^3 35·36, H^2O 16·94 = 100; affording the oxygen ratio for the antimony, iron and water 1·1 : 1 : 1·4; taking it at 1 : 1 : 1·5, it corresponds to 2 of sesquioxides of antimony and iron to 3 of water.—*Proc. Acad. Nat. Sci. Philad.*, p. 366, 1873.

12. *Chromite and Trautwinite from Monterey Co., California;* by E. GOLDSMITH. Proc. Acad Nat. Sci. Philad., 1873, p. 365.—Analyses afforded

	Si	Cr	Fe	Al	Ca	Mg	
Chromite,	12·12	52·12	15.24	2·18	5·65	12·29	sp. gr. 4·1647
Trautwinite,	21·78	38·39	13·29	0·81	18·58	7·88	" 3·505

Mr. Goldsmith concludes that the trautwinite is a result of the alteration of chromite; and that the silica and lime found in this chromite is in the state of trautwinite. The mineral is not acted on by hydrochloric acid.

13. *Dr. Regel on Vitis*, a Monograph recently published in the Annals of the St. Petersburgh Botanic Garden, we commend to the notice of Dr. Engelmann, as being most familiar with the botany of our North American Vines and their near relatives. One need not know them profoundly, however, to be able to appreciate the soundness of the judgment that combines under one species, *V. cordifolia* (our Frost Grape) with *V. vulpina*, the Muscadine or Southern Fox Grape!

The Gardener's Chronicle calls attention to Dr. Regel's bringing forward as an "objection to the Darwinian theory, the circumstance that the cultivation of the American vines has resulted, in the course of a few score of years, in the production of as great an amount of variation as has been obtained in Enrope and Asia during tens of centuries." Upon which it may be remarked, 1, that there are in North America several species to work with, against the single one cultivated in Europe and western Asia; and, 2, that the American varieties in question for the most part have not been made, but rather selected and improved within the last two or three score years. As most youngsters here very well know, all our Vines vary greatly as to their fruit in the wild state. So that nature had long ago begun the work which the cultivator in this case only accelerates, and directs, and gets the credit for.

A. G.

14. *Hepaticæ Boreali-Americanæ;* by Coe F. Austin. Closter, New Jersey, 1873.—This classical collection, which is very important for those who undertake to collect and study our *Hepaticæ*, was announced, if we mistake not, some time ago. The sets are now issued, with tickets, index, and title-page, making a choice collection of 150 species. The tickets are in English, except the characters of new species, which are in Latin. The number of sets is limited; the price $15, but soon to be raised. A separate pamphlet is issued, of 48 pages, octavo, containing the tickets, index, &c., of the collection. Following the orthography of Jungermann's name, the familiar genus dedicated to him is *Jungermannia*, which Mr. Austin has shortened to *Jungermania*. A. G.

15. *Ilysanthes gratioloides*, a rather insignificant plant of our flora, has recently been found in abundance in France, in the neighborhood of Nantes. It is thought to have appeared there between the years 1853 and 1858, and to have been in some way received from the United States, but the manner of its coming eludes enquiry. An account of it is given in Bull. Bot. Soc. France, session of Nov. 15, 1872. A. G.

16. *Synopsis Generis Lespedezæ, auctore* C. I. Maximowicz.—This fills sixty pages of the Annals of the St. Petersburgh Botanic Garden, and was presented at its semi-centennial celebration on the 22d of March last. The genus is one of those mainly divided between the eastern United States and eastern Asia, chiefly Japan and China, and so comes especially before Dr. Maximowicz, who is working up the Flora of Japan. We found our own species difficult when we studied them more than thirty years ago; we welcome the light which a new study of the whole genus is likely to throw upon them, and are quite prepared to accept, after verification (upon the first convenient opportunity), the moderate changes which Dr. Maximowicz concludes to make. We trust, and indeed should expect, that his characters may serve to distinguish from *L. violacea* the *L. reticulata*, including *L. sessiliflora* and our variety *angustifolia*; the junction of *L. procumbens* with *L. repens* confirms a view which some of our American botanists had already insisted on; and, as to the *angustifolia* variety of *L. capitata*, with its rounded legumes not surpassed by the calyx and sometimes slender peduncles, it is well separated from that species, but is more likely to be a distinct species than a form of *L. hirta*. As to the "clandestine" or "apetalous" flowers of one section, which Maximowicz would prefer to call "female" (none of which names are truly apt), we request our botanists in the field to scrutinize them. They are probably *cleistogenous*. As to Bertoloni's *L. cytisoides*, it is of course *Pitcheria galactoides* of Nuttall; and we thought this had been stated in this Journal, among the notices of poor old Bertoloni's remarkable doings. As to *L. striata*, the type and sole representative of his third sub genus, *Microlespedeza*, Dr. M. is unaware of the singular fact of its recent, and singular, seemingly unaccountable, naturalization and wide diffusion in our southern Atlantic States, where

it is said to be of inestimable value as a "forage plant." There are notices of it in this Journal, eight or ten years ago: these would have supplied the author of this monograph with materials for amplifying his paragraph upon the use of Lespedezæ. A. G.

17. *On the Systematic Position of the Brachiopoda;* by E. S. MORSE. (From the Proceedings of the Boston Society of Natural History, vol. xv, 1873.) 60 pages, with numerous figures.—In this memoir Professor Morse has presented, at some length, his arguments in favor of uniting the Brachiopods with the Chætopod Worms. His avowed object is "to show that in every point of their structure, the Brachiopoda are true worms, with possibly some affinities to the Crustacea, and that they have no relations to the Mollusca, save what many other worms may possess in common with them."

In this and several other valuable papers on the Brachiopods the author has presented many facts of great interest and importance concerning their anatomy and embryology, and for these he deserves much credit, whether we accept his theories concerning their relations to the worms, or not. A full discussion of his theory and arguments, on this subject, will not be attempted at this time; but as some of his statements are calculated to mislead those not familiar with the subject, a few exceptions to such statements may not be out of place. On pages 7 to 10 (319 to 322, in Proc.) a summary is given of the characters in which Worms and Mollusks are supposed to differ; and on pages 58 and 59, the characters of "Vermes" and Brachiopods are compared in parallel columns. In both places the terms "worms," "Vermes," "Annulata," are used so indefinitely that it is not always easy to tell whether certain characters are intended to apply to all worms, or "vermes," or to particular groups, like the Annelids. But considering the immense diversity in the anatomy and embryology of the numerous groups, of at least ordinal value, if not classes, already referred to the "Vermes," this distinction is of essential importance. Thus it would be easy to show that there are exceptions (often very numerous) to nearly every character given as characteristic of "Vermes" on pp. 58, 59. It would also be easy to show that part of the characters given as common to Vermes and Brachiopods are common, likewise, to most other classes of Invertebrata, including certainly some Mollusks and Radiates.

The first character given (p. 7) relates to form: "We have in the Vermes a form, whose length is much greater in proportion to its breadth than in the Mollusks." Many Annelids, like *Aphrodite*, *Euphrosyne*, certain leeches, and many of the lower "Vermes," like the Planarians, are notable exceptions, being relatively broader and shorter than the majority of Mollusks. Again, "the worm is perfectly bilaterally symmetrical, depressed, flattened or circular, the dorsal and ventral regions so near alike in many cases as to be distinguished with difficulty, and the body never flattened laterally," the reverse being stated of the Mollusks. But we find many Annelids that are more or less asymmetrical,

either in the number and form of the jaws (*Diopatra*, etc.), or in the cephalic appendages, as in *Serpulidæ*, where one of the branchiæ, on one side, is often transformed into an operculum; or in various other organs, in different groups; while the dorsal and ventral regions are often quite as strongly contrasted as in any mollusk; and in some cases the body is compressed laterally (*Ammotrypane*). But on the other hand, mollusks are often nearly or quite symmetrical (many Nudibranches, Chitons, Pteropods, Cephalopods) and are frequently cylindrical or even depressed (*Doris*, Chitons, Cephalopods, Pteropods). In fact *form* is a very poor character for characterizing any large group of animals, and should have little or no weight in this case. The ventral connections of the "locomotor muscles" in mollusks and their lateral and dorsal attachment to the integument in worms are given as distinctive. But we generally find the locomotor muscles of animals connected with the locomotive organs, wherever these may be situated. So in *Pecten* we find that the main locomotor muscles are attached laterally to the shell, that being its principal organ of locomotion; and in Cephalopods we find them on the sides and back, as well as ventrally, so that the mantle may be used as a locomotive organ. On the other hand, many worms, like *Aphrodite*, *Lepidonotus*, many leeches, Trematodes, and other worms, both high and low, have their locomotive organs as truly ventral as those of Gastropods. "In the Mollusk the tegumentary envelope is prolonged, and oftentimes continuous, forming a sac or mantle, inclosing a conspicuous cavity, and protecting the gills." This is, indeed, a valuable character, but not accurately stated, for the mantle does not always form a "cavity," and is often nearly or quite abortive, and the gills are often situated on the back or sides, as in the Nudibranchs. But in this character the Brachiopods agree with the Mollusks, and not with the worms. "In the worm the digestive canal is straight, rarely convoluted, and suspended freely in the perivisceral cavity." "In the Mollusk, the intestine is always convoluted, not suspended freely in the perivisceral cavity, but intimately blended, or united with other organs." The intestine varies immensely in both groups, according to the food of the species, and cannot be properly used as a character for separating two sub-kingdoms. Among Sipunculoid Worms (as stated on p. 26) the intestine is generally very long and greatly convoluted, and may terminate either anteriorly or posteriorly.

In most Nemerteans, Planarians, and Trematode worms the intestine is not "freely suspended," but firmly united to the other organs and the tegumentary system. 'In Vermes there is a peculiar depuratory apparatus characteristic of all. In the Annulata this apparatus takes the shape of bilaterally symmetrical tubes, in pairs, opening externally and communicating with the perivisceral cavity, by distinct independent infundibuliform orifices. In the Mollusca, with the exception of certain Cephalopoda, nothing of the kind is found, and where such communi-

cation does exist between the organs and the surrounding medium, it is by means of simple orifices in the walls of the cavity." The "depuratory apparatus" of "Vermes" is so diverse in structure and position in the different groups, as to render it very questionable whether these organs are homologous in the different orders. Moreover, there is still so much to learn concerning both the proper vascular circulation and the "depuratory apparatus" of ordinary Mollusca, and the connection of both with the exterior, that it is very unsafe to base generalizations on negative evidence of this kind. Even now, the utmost diversity of opinion exists, among the leading European anatomists, concerning the character of these organs in the commonest Mollusks, some asserting and others denying the existence of external vascular connections, lacunæ, capillaries, etc. It should also be considered that no "segmental organs" have yet been detected in the nearest allies of the Annelids, the Crustacea, although the two classes agree so closely in nearly all other respects that no one has been able, as yet, to frame strictly distinctive diagnoses for them. Nevertheless the existence of the infundibuliform organs in Brachiopods is certainly one of their most remarkable characters; and also one of the strongest analogies with the Annelids which they possess.

The character of the nervous system of Brachiopods, according to the author's own statements, is quite as much like that of a degraded mollusk as like that of a degraded worm, and has no special resemblance whatever to that of any of the true Annelids, with which the author wishes to compare them. We may as well compare it with the nervous system of a Lamellibranch, without the pedal and posterior ganglia (for which there is no use), as with that of an Annelid destitute of the ventral series of ganglia. "In the Annulata, with the exception of the Discophora, the generative products are set free in the perivisceral cavity, receiving from the fluid therein contained certain nourishment." Another notable exception is found in the common earth-worms, and their allies, which have a distinct oviduct and male organ, in the median line beneath, and, like many leeches, lay eggs enclosed in capsules, not unlike those of many mollusks. Other exceptions also occur in the Annelids, while among the Cestodes, Trematodes, Nematodes, and Turbellaria, the oviduct is usually single and connected directly with the ovary, as in most Mollusca. But in Polyps and many common Fishes, etc., the generative products are discharged into the perivisceral cavity, as in most Chætopod Annelids. This is obviously a character of small importance, hardly sufficient to characterize even the several *orders* of Annelids. In the Mollusca, "with the exception of the Octopoda, the oviduct is single." Many other exceptions occur, in the Chitons, Lamellibranchs, etc. "Among the Mollusks, even when devoid of a shell in the adult, the embryo early develops a shell composed of one or two pieces." This is not the case in many Cephalopods and Pteropods.

From this summary it will be seen that not one of the characters given to worms is, properly speaking, characteristic, or diagnostic, of the Vermes, as a whole, and few of them can be applied to more than a single order, while many of them are common to the worms and various other invertebrates, belonging to diverse classes and branches, including Mollusca. The same remarks apply to most of the additional characters given to Vermes, on pp. 58, 59. Some of the latter are even more useless, as distinctive of Vermes. Thus they are said to have "an extensive vascular system, containing a colored fluid representing the pseudo-hæmal system." This has not usually been given as a character for all Vermes," but merely for the higher Annelids; but it does not hold good even within those limits, for there are many Chætopod Annelids, belonging to several different families, that are totally destitute of pseudo-hæmal vessels, but have only one fluid, which fills the perivisceral cavity, (*Aphlebina*, *Polycirrus*, *Glycera*, etc.), and yet some of these genera belong to families in which other genera have a complete system of vessels, (see also Morse's quotation from Claperède, p. 25). The possession of "chitinous outgrowths, either as scales, plates, hairs, or spines" is a character that applies only to a part of the true Annelids, most leeches and many Sipunculoids, as well as most of the Helminths (except in the embyos of some) being destitute of such appendages. In fact most of these characters are no more characteristic of worms, as a group, than the presence of a shell is characteristic of Mollusca.

These facts are brought forward, not for the purpose of refuting Prof. Morse's views concerning the position of Brachiopoda, which, if established at all, must rest on other and better foundations, but to show how vague are his definitions of "Vermes," and how indefinite his ideas as to what a *worm* really is. The difficulty of defining the heterogeneous group of "Vermes" would be greatly increased by adding to it the Brachiopods and Polyzoa, as the author proposes. Nor can he better the matter, by separating the "Vermes" from the rest of the Articulata, and calling the group a "sub-kingdom," as some other writers have alreany done. In fact, there is far greater difference between the Annelids and lower worms (Helminths), than between the Annelids and Crustacea. These two last classes approximate so closely in structure, in some of their forms, that it has become a matter of extreme difficulty to find diagnostic characters for separating them, and few greater absurdities have been proposed in classification, in modern times, than to separate them in two "sub-kingdoms" or branches. On the same basis every class of animals might be made a "sub-kingdom."

Another feature of the arguments presented demands attention from those who may wish to form an impartial judgment of them. The author naturally takes great pains in every case to point out all the resemblances between the organs of worms and those of Brachiopods that he compares, but he does not always allude to the *differences*. Thus, on p. 11, he compares the elongated

caudal segments of Annelids, like *Pectinaria* and *Sabellaria*, with the peduncle of Brachiopods, but he does not mention the fact that in the former the anal orifice is at the end of the caudal segment, which is bent forward, and that this elongation is to facilitate the discharge of the fæces; while the peduncle of Brachiopods is imperforate, does not contain the intestine, and is essentially an organ of attachment. The fabrication of tubes by the agglutination of sand with a mucous secretion, in *Lingula*, is a character of trivial importance, for many soft bodied species of nearly all classes of invertebrates, whether Protozoa, Radiata, Mollusca, or Articulata, do the same thing. On p. 28, the identity of the cirri of Brachiopods and Annelids is asserted, but he has not mentioned that in the latter these organs are genuine gills, with a complicated capillary vascular circulation, which has not been shown to exist in the former. So of the pallial membranes of Brachiopods and the collar of Annelids, he has shown their points of resemblance, but has largely ignored their great differences in structure, relations, and function. We would also remind our readers that a liberal use of printers-ink on diagramatic cuts, like those on page 21, may serve to conceal differences, as well as to show resemblances.

The facts in regard to the embryology of the Brachiopods, which are brought out by Prof. Morse in this and in a subsequent memoir, are of great interest and importance, and do, indeed, show remarkable points of resemblance between the embryos and larvæ of Brachiopods and of certain worms. A. E. V.

18. *Occurrence of Gigantic Cuttle-fishes on the coast of Newfoundland;* by A. E. VERRILL.—Considerable popular interest has been excited by several articles that have recently been published and extensively circulated in the newspapers of Canada and the United States, in regard to the appearance of gigantic "squids" on the Newfoundland coast. Having been so fortunate as to obtain, through the kindness of Prof. S. F. Baird, the jaws and other parts of two of these creatures, and, through the courtesy of Dr. J. W. Dawson, photographs of portions of two other specimens, I have thought it worth while to bring together, at this time, the main facts respecting the several specimens that have been seen or captured recently, so far as I have been able to collate them, reserving for a future article the full descriptions and figures of the jaws and other portions, now in my possession.

We now have reliable information concerning five different examples of these monsters that have appeared within a short period, at Newfoundland. (1). A specimen found floating at the surface, at the Grand Banks, in October, 1871, by Captain Campbell, of the schooner B. D. Haskins, of Gloucester, Mass. It was taken on board and part of it used for bait. Dr. A. S. Packard has given, in the American Naturalist, vol. vii, p. 91, Feb., 1873, all the facts that have been published in regard to this individual. But its jaws have since been sent to the Smithsonian Institution, and are now in my hands to be described and figured. They were thought

by Professor Steenstrup, who saw a photograph of them, to belong to his *Architeuthis monachus*, which inhabits the northern coasts of Europe, but is still very imperfectly known. The horny jaw or beak from this specimen is thick and strong, nearly black; it is acute at the apex, with a decided notch or angle on the inside, about ·75 of an inch from the point, and beyond the notch is a large prominent angular lobe. The body of the specimen from which this jaw was taken is stated to have measured 15 feet in length and 4 feet 8 inches in circumference. The arms were mutilated, but the portions remaining were estimated to be 9 or 10 feet long, and 22 inches in circumference, two being shorter than the rest. It was estimated to weigh 2000 pounds.

(2). A large individual attacked two men, who were in a small boat, in Conception Bay, and two of the arms which it threw across the boat were cut off with a hatchet, and brought ashore. Full accounts of this adventure, written by Mr. M. Harvey, have been published in many of the newspapers.* One of the severed arms, or a part of it, was preserved in the museum at St. John, and a photograph of it is now before me. This fragment represents the distal half of one of the long tentacular-arms, with its expanded terminal portion covered with suckers, 24 of which are larger, in two rows, with the border not serrate, but 1·25 inch in diameter; the others are smaller, very numerous, with the edge supported by a serrated calcareous ring. The part of the arm preserved measured 19 feet in length, and 3·5 inches in circumference, but wider, "like an oar," and 6 inches in circumference, near the end where the suckers are situated; but its length, when entire, was estimated at 42 feet.† The other arm was destroyed and no description was made, but it was said to have been 6 feet long and 10 inches in diameter; it was evidently one of the eight shorter sessile arms. The estimate given for the length of the "body" of this creature (60 feet) was probably intended for the *entire length*, including the arms.

(3). A specimen was found alive in shallow water, at Coomb's Cove, and captured. Concerning this one I have seen only newspaper accounts. It is stated that its body measured ten feet in length and was "nearly as large round as a hogshead" (10 to 12 feet); its two long arms (of which only one remained) were forty-two feet in length and "as large as a man's wrist;" its short arms were six feet in length, but about nine inches in diameter, "very stout and strong;" the suckers had a serrated edge. The color was reddish. The loss of one long arm and the correspondence of the other in size to the one amputated from No. 2, justifies a suspicion that this was actually the same individual that attacked the boat. But if not, it was probably one of the same species, and of about the same size.

* Also in the Annals and Magazine of Natural History, January, 1874, with a wood-cut of the arm.

† Doubtless these long arms are very contractile and changeable in length like those of the ordinary squids.

(4). A pair of jaws and two of the suckers were recently forwarded to me from the Smithsonian Institution. These were received from Rev. A. Munn, who writes that they were taken from a specimen that came ashore at Bonavista Bay; that it measured thirty-two feet in length (probably the entire length, including more or less of the arms); and about six feet in circumference. This jaw is large and broad, but much thinner than that of No. 1, and without the deep notch and angular lobe seen in that specimen. It probably belongs to the *Architeuthis dux* of Steenstrup, or at least to the same species as the jaw figured by Dr. Packard.

(5). A smaller specimen, captured in December, in Logic Bay, about three miles from St. John, in herring nets. Of this I have a description in a letter to Dr. Dawson, from M. Harvey, Esq., who has also published a brief account of it in the "Morning Chronicle," of St. John. The letter is acompanied by two photographs of the specimen: one showing the entire body, somewhat mutilated anteriorly; the other showing the head with the ten arms attached. The body of this specimen was over seven feet long, and between five and six feet in circumference; the caudal fin was twenty-two inches broad, but short, thick, and emarginate posteriorly on each side, the end of the body being acute; the two long tentacular-arms were twenty-four feet in length, and two and a half inches in circumference, except at the broader part near the end; the tips slender and acute; the largest suckers 1·25 inch in diameter, with serrated edges; the eight short arms were each six feet long; the two largest were ten inches in circumference at base; the others were 9, 8 and 7 inches. These short arms taper to slender acute tips, and each bears about 100 large, bell-shaped suckers, with serrated margins. Each of the long arms bear, about 160 suckers on the broad terminal portion, all of which are denticulated; the largest ones, which form two regular alternating rows, of twelve each, are about an inch in diameter. There is also an outer row of much smaller suckers, alternating with the large ones, on each margin; the terminal part of these arms is thickly covered with small suckers: and numerous similar small suckers are crowded on that portion of the arms where the enlargement begins, before the commencement of the rows of large suckers. The arrangement of the suckers is nearly the same as on the long arm of No. 2, but in the latter the terminal portion of the arm, beyond the large suckers, as shown in the photographs, is not so long, tapering, and acute, but this may be due to the different conditions of the two specimens. It is probable that this was a young specimen of the same species as No. 2.

From the facts known at present, it appears probable that all these specimens, and several others that have been reported at various times from the same region, are referable to two species; one (probably *Architeuthis monachus*) represented only by the first of those enumerated above, and having a more elongated form of body and stouter jaws; the second (probably *A. dux*) represented by Nos. 2 to 5, above described, having a short,

thick, massive body, and broad, but comparatively thin jaws, which are also different in form. Some of the differences in size and proportions, and in the suckers, observed among the four specimens referred to the latter species, may be due to sex, for the sexes differ considerably in these characters in all known cuttle-fishes.

19. *Revision of the Echini;* by ALEXANDER AGASSIZ. Part iii, 4to, with 45 plates. Illustrated Catalogue of the Museum of Comparative Zoölogy. Cambridge, Mass. 1873.—This excellent work is profusely illustrated by unique plates, a large part of which have been made by different photographic printing processes, directly from photographs of the specimens, and are of unrivalled excellence. The Woodbury-type process, the Albert-type and the Heliotype, have all been successfully employed, while superior lithographs have also been used to some extent. Part iii. contains detailed descriptions of all the known species, except those of the east coast of North America, which were described in Part ii. Such species are, however, referred to, in their proper systematic places. Twenty-eight plates illustrate Part iii; the remaining seventeen relate to structure and belong to Part iv, but are issued in advance of the text, owing to the loss of the MSS., drawings, and some of the plates, by the great Boston fire, in November, 1872. A. E. V.

20. *The Marine Mammals of the Northwestern Coast of North America, described and illustrated, together with an account of the American Whale-fishery;* by CHARLES M. SCAMMON, Captain U. S. Revenue Marine. San Francisco: John H Carmany & Co. 4to.—The advance copies of the plates of this work, that we have seen, are highly satisfactory, and considering the well known ability and enthusiasm of the author, we anticipate that the book, when completed, will be a valuable contribution to science, in a department which is still very imperfectly understood, and of great importance economically. The work deserves, and should receive, the support of all who are interested in promoting the study of Natural History. It is to be illustrated by thirty or more lithographic plates, and is offered to subscribers at the very low cost of ten dollars. A. E. V.

21. *Embryology of Terebratulina;* by E. S. MORSE. From the memoirs of the Boston Society of Natural History, vol. ii, p. 249–264, 4to, with two steel plates. December, 1873.—A longer notice of this important memoir is deferred to the next number.

22. *Crustacea common to Lake Superior and the lakes of northern Europe;* by S. I. SMITH.—The occurrence of *Mysis relicta* Lovén and *Pontoporeia affinis* Lindström in Lakes Superior and Michigan has already been alluded to in this Journal (vol. ii, pp. 373 and 448, Nov. and Dec., 1871). In recently examining the collection made in Lake Superior in 1871, under the direction of the Superintendent of the Lake Survey, I have found three species of Cladocera which I cannot distinguish from species described from the lakes of northern Europe. *Daphnia galeata* G. O. Sars

and *D. pellucida* P. E. Müller were taken at the surface a few miles south of the island of St. Ignace and also came up in the dredge at the same locality. These species both agree fully with the detailed figures and descriptions given by Müller.*

A single specimen of *Leptodora hyalina* Lilljeborg† came up in the dredge with the last species and, like them, was undoubtedly taken in the dredge on its way up. This last species is one of the largest and most remarkable forms of Cladocera known. It is wholly transparent and grows to fully half an inch in length. The shell is very small and incloses no part of the body; the head with the large eye at its extremity is produced far forward; the basal portion in the natatory appendages is long and very stout, while the rami are comparatively short and four-jointed; the six pairs of legs are crowded together below the natatory appendages; and the abdomen is very long and the last segment terminates in two stout stylets.

23. *The American Limulus polyphemus on the Dutch coast.*— This species of Limulus, familiarly known on the American coast as the Horse-shoe or King-crab was taken in July last, according to Mr. Edward Newman, about eleven miles off the Shelling Light on the Dutch coast, by the Yarmouth trawl boats. Four or five have been taken in all during the summer. One is reported to have been captured on the coast of North Wales.—*Harper's Weekly*, Jan. 24.

III. Astronomy.

1. *Contributions to Solar Physics.* I. A popular Account of Inquiries into the physical constitution of the Sun, with special reference to recent Spectroscopic Researches; II. Communications to the Royal Society of London and the French Academy of Sciences, with Notes. By J. Norman Lockyer, F.R.S. London: Macmillan and Co. 1874. pp. xxi, 676, 8vo.—The purpose of this beautiful volume, which has just been issued by Messrs. Macmillan and Co., is sufficiently indicated in the above title to render any extended notice unnecessary. The first part is a popular exposition of the facts and principles necessary to a good understanding, on the part of the general reader, of the recent acquisitions in spectroscopy, and the results of its application to the study of solar physics. It is made up, for the most part, of lectures of the author delivered at the Royal Institution and elsewhere, upon the sun, solar eclipses, and the spectroscope, and of essays which he has published at different times in various periodicals. The second part contains, besides the numerous papers of the author giving account of his own researches and discoveries, copious statements of the part other investigators have had in the achievements of spectroscopic analysis, and its application. The

* Denmark's Cladocera, Naturhistorisk Tidsskrift, III, vol. v, p. 116, 117, pl. 1, figs. 5, 6.

† Oversight af Kongl. Vetenskaps-Akademiens Förhandlingar, 1860, p. 265, pl. 7, figs. 1–22; Müller, loc. cit., p. 226, pl. 6, figs. 14–21.

work is enriched with numerous illustrations and maps of spectra, and much new matter is added in the notes. The manner in which this portion of the work is made up gives it especial value, as it is not a mere *résumé*, but gives the original papers either fully, or in extended extracts. Information of the highest interest is thus brought to readers, to most of whom, perhaps, the original memoirs are inaccessible. A. W. W.

2. *The Analyst: a Monthly Journal of Pure and applied Mathematics;* edited and published by J. E. HENDRICKS, A.M., Des Moines, Iowa.—This is the first number of a journal "intended to afford a medium for the presentation and analysis of any and all questions of interest or importance in pure and applied mathematics, embracing especially, all new and interesting discoveries in theoretical and practical astronomy, mechanical philosophy, and engineering." Each number is to consist of not less than sixteen pages, and the price is two dollars a year. Among the articles in this number are: the relative positions of the asteroidal orbits, by Prof. Kirkwood; the recurrence of eclipses, by Prof. D. Trowbridge; operations on imaginary quantities considered geometrically, by Prof. Henkle; equations of differences, by Mr. Siverly; relation between the mean and true anomaly, by Prof. Ficklin; etc. A journal covering this field is needed in this country, and we most heartily wish it the highest success.

3. *An investigation of the Orbit of Uranus, with general tables of its Motion;* by SIMON NEWCOMB, Prof. Mathematics, U. S. N. Smithsonian Contributions. 4to, pp. 288.—The first chapter of this elaborate work, is a development of a method of determining the pertubations of the longitude, radius vector and latitude of a planet by direct investigation. This theory is then applied to the action of the three other large planets upon Uranus. An exhaustive discussion of all the good observations of the planet from 1690 onward, and extended tables of its motion complete the work.

4. *Astronomical Suggestions;* by H. M. PARKHURST.—(1.) By the method of "extinguishing apertures," accuracy of results can only be obtained with a perfectly dark field. It is evident that a star is more easily seen in a black field than in one which is illuminated; and that, with an equal magnifying power the illumination will vary in proportion to the aperture. The error may exceed one magnitude.

(2.) A transit may be observed by the spectroscope when there is a near approach but no actual contact. This method will not be applicable to a transit of Venus before the year 2490; but may be applied to transits of Mercury or the moon. Mercury in the conjunction of Nov., 1874, will pass near the sun's limb, but probably not near enough to be seen.

5. *Astronomical Engravings from the Observatory of Harvard College.*—We omitted to notice some weeks since the receipt of Nos. 20–22 of this series (see this Journal, v, 319), which contain representations of the lunar mountains Linné, Gassendi, Plato, Aristarchus and Herodotus, a key to the lunar surface, and four views of the planet Mars.

6. *Tableau de l'Astronomie dans l'Hémisphère Austral et dans l'Inde;* by Dr. E. MAILLY, Bruxelles, 8vo, pp. 232. Extract from the 23d vol. of Memoirs of the Royal Academy of Belgium.—This is an interesting and minute account of the equipment of all the observations in the southern hemisphere and India, with the work accomplished in each from Halley's formation of a catalogue at St. Helena in 1677, of 341 southern stars, to the establishment of the observatory at Cordoba, by Dr. Gould.

7. *Aurora Australis.*—The Aurora was seen at Sandhurst in Victoria, on the 19th of May, 1873, at 10 P. M.—*Monthly Record Melbourne Observatory, during May*, 1873.

IV. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *American Metrological Society.*—On the 30th of December, a number of gentlemen met at Columbia College, pursuant to a call issued by Pres. F. A. P. Barnard, and formed the *American Metrological Society.* Hon. J. A. Kasson presided, and a constitution was adopted and officers elected. The objects of the society are stated to be to originate measures or to aid in promoting measures elsewhere originating, designed to improve the system of weights, measures, and moneys at present existing among men, and to bring the same into relations of simple commensurability with each other.

An object secondary to this will be to secure the universal adoption of common units of measures for the expression of quantities which require to be stated in presenting the results of physical observation or investigation, and for which the ordinary systems of metrology do not provide—such as the divisions of the barometer, thermometer, and densimeter; the amount of work done by machines; the amount of mechanical energy, active or potential, of bodies, as dependent on their motion or position; the quantities of heat present in bodies at given temperatures or generated by combustion or otherwise; the quantity and intensity of electro-dynamic currents; the aggregate or efficient power of prime movers; the accelerative power of gravity; the pressure of steam and of the atmosphere, and other matters analogous to these. The Association will endeavor also to secure uniformity of usage in regard to standard points of reference, or to those physical conditions to which observations must be reduced for purposes of comparison, especially the temperature and pressure to which are referred the specific gravities of bodies and the zero of longitude on the earth. The following officers were chosen:

President, Dr. F. A. P. Barnard; *Vice-President*, Hon. John A. Kasson; *Recording Secretary*, Prof. C. G. Rockwood. Jr.; *Corresponding Secretary*, Prof. S. D. Tillman; *Treasurer*, Howard Potter, Esq.; *Council*, S. B. Ruggles, Esq., Profs. H. A. Newton, T. R. Pynchon, J. E. Hilgard, Wolcott Gibbs, and C. S. Lyman, E. B. Elliott, Esq., Profs. J. P. Cooke, R. W. Raymond, and R. H. Thurston.

2. *Gold and Silver production in* 1873.—Mr. JOHN J. VALENTINE, General Superintendent of Wells, Fargo & Co. Express agency, through whose hands most of the bullion of the Pacific coast of North America passes, has furnished the "Alta California," of Jan. 1, 1874, with the following tabular statement of the precious metals for 1873.

Statement of Precious Metals produced in States and Territories West of Missouri River, during 1873.

States and Territories.	Gold Dust and Bullion by Express.	Gold Dust and Bullion by other conveyances.	Silver Bullion by Express.	Ores and Base Bullion by Freight.	Total.
California	$15,709,956	$1,570,995	$ 264,771	$480,000	$18,025,722
Nevada	219,141	43,828	30,183,921	4,807,617	35,254,507
Oregon	1,146,991	229,398	-------	------	1,376,389
Washington	171,951	34,390	3,054	------	209,395
Idaho	1,171,131	234,226	938,297	------	2,343,654
Montana	3,241,238	648,247	3,325	------	3,892,810
Utah	112,003	22,400	1,210,434	3,561,500	4,906,237
Arizona	37,074	7,415	3,289	------	47,778
Colorado	1,856,639	--------	839,862	1,386,767	4,083,268
Mexico	--------	--------	868,798	------	868,798
British Columbia	1,041,696	208,339	--------	------	1,250,035
Total	--------	--------	--------	------	$72,258,693

This aggregate is over $10,000,000 in excess of the like statement for 1872. The increase in Nevada alone is nearly $10,000,000, and the total product of Nevada nearly equals that of all the others. Arizona, California, British Columbia, Oregon, Washington, Idaho and Montana have diminished. Nevada, Utah and Colorado increased. Arizona is imperfectly represented, but her entire production is small at most. The production of Mexico is represented very imperfectly and in silver only, because the great bulk of the bullion of Mexico reaches market by other channels than Wells, Fargo & Co., who report only what they have themselves transported. The combined product of all shows for 1872, $62,236,913 and for 1873, $72,258,693, which exceeds the product of any previous year for these regions.

3. *United States Geological Survey of the Territories.*—The United States Geological Survey of the Territories has in press at this time, at the Government Printing office, the following works.

A volume on the Ornithology of the northwestern territories. It has been prepared by Dr. E. Coues, the well known ornithologist. The synonomy has been worked out with care and the descriptions are given of four-fifths of the birds known to exist west of the Mississippi. The volume will form, No. 3 "Miscellaneous Publications," and will contain from 800 to 1000 pages, 8vo. It will not be ready for distribution before Spring.

No. 4 of the "Miscellaneous Publications," the Synopsis of the Flora of Colorado by Prof. T. C. Porter and John M. Coulter, is in type and will be ready in a few days. It will form an octavo volume of about 250 closely printed pages, and contain a list of

over 1400 species. "The plan followed in the Synopsis is, that of Mr. Watson in his excellent Catologue vol., 5, of Clarence King's Report. Descriptions are given of all the orders, genera and species not contained in Gray's Manual, Chapman's Flora, and other Botanies of the States east of the Mississippi river." The mosses, lichens, and fungi are included. About fourteen new species are here described for the first time. The work will form a convenient hand-book for botanical tourists to the mountainous districts of Colorado.

Volume vii of the quarto series, on the Cretaceous Flora of the West, prepared by Leo Lesquereux, will be ready for the printer by the end of January. The plates, 28 in number, have been engraved on stone by Mr. Julius Bien, of New York, and will be printed in tints.

It is stated to be the intention of the Survey that the quarto series shall be published in the best style, both as to printing, quality of paper, and character of illustrations.

4. *First Book of Geology;* by WILLIAM S. DAVIS, LL.D., Head Master of the Derby Central School of Science. 160 pp. 12mo, with 115 illustrations. — Putnam's Elementary Science Series. New York (G. P. Putnam's Sons). Reprinted from the English edition. A good little geological school book, based in its stratigraphical and historical part mainly on facts in British geology.

5. *Das Elbthalgebirge in Sachsen von* Dr. H. B. GEINITZ. Cassel, 1873. (Theodore Fischer.)—The sixth number of Part I, and the third of Part II, of Dr. Geinitz's important work have been issued. The former contains a continuation on the Pelecypoda of the Lower Quader (Middle Cretaceous) and is well illustrated by seven quarto plates, partly by Miss Elise Geinitz. The latter treats of species of the same tribe from the Middle and Upper Quader (Upper Cretaceous) and includes six plates.

6. *Academy of Sciences of France.*—J. Norman Lockyer has been elected a correspondent, to fill the place rendered vacant in the Astronomical section by the death of Encke: and Messieurs Angström and Billet in place of Hansteen and Wheatstone.

Reliquiæ Aquitanicæ, being contributions to the Archæology and Palæontology of Périgord and the adjoining provinces of Southern France; by Edouard Lartet and Henry Christy; edited by Thomas Rupert Jones, R.S. and G.S., etc. Part XIII, Nov., 1873; pages 173–188 and 153–164. Plates A. xxxvii–xxxix, and B xxv–xxvii. This new number of the Reliquiæ Aquitanicæ has recently been received.

ERRATA.

Vol. v, p. 432, 22d line from foot, for synclinal, read anticlinal.

p. 419, line 4 from foot, for 14·51 read 14·15.

p. 424, line 11 from foot, dele "and subtracting 1."

p. 425, in the note read—Q in this paper=$\mathfrak{B}$ of Maxwell; Q′=Q of Maxwell; $4\pi M=\mathfrak{H}$ of Maxwell; $\frac{Q}{4\pi}-M=\mathfrak{J}$ of Maxwell.